1   **Temporal dynamics of marginal steppic vegetation over a 26-year period of**

2   **substantial environmental change**

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Abstract

Questions: 1. Is climate a strong driver of vegetation dynamics, including interannual variation, in a range-margin steppic community? 2. Are there long-term trends in cover and species richness in this community, and are these consistent across species groups and species within groups? 3. Can long-term trends in plant community data be related to variation in local climate over the last three decades?

Location: A range-margin steppic grassland community in Central Germany.

Methods: Cover, number and size of all individuals of all plant species present in three permanent 1-m^2 plots were recorded during spring for 26 years (1980 to 2005). Climatic data for the study area was used to determine the best climatic predictor for each plant community, functional group or species variable (annual data and interannual variation) was determined with best-subsets regression.

Results: April and autumn temperature showed the highest correlations with both total cover and species richness and interannual variation of cover and richness. However, key climate drivers differed between the five most abundant species. Likewise, total cover and number and cover of perennials significantly decreased over time, while no trend was found for the cover and number of annuals. However, within functional groups there were again contrasting species-specific responses. Long-term temperature increases and high interannual variability in both temperature and precipitation were strongly related to long-term trends and interannual variation in plant community data.

Conclusions: Temporal trends in vegetation were strongly associated with temporal trends in climate at the study site, with key roles for autumn and spring temperature and precipitation. Dynamics of functional groups and species within groups and their relationships to changes in temperature and precipitation reveal complex long-term and interannual patterns that cannot be inferred from short-term studies with only one or a

1 few individual species. Our results also highlight that responses detected at the

2 functional-group level may mask quite contrasting responses within functional groups.

3 We discuss the implications of these findings for attempts to predict the future response

4 of biodiversity to climate change.

5 **Keywords**: range-margin plant communities, climate change, perennial and annual

6 plants, cover, species richness

7 **Nomenclature:** Jäger & Werner (2005).

8

9 **Introduction**

10 Long-term vegetation data provide a unique opportunity to understand vegetation

11 dynamics, including interannual variability in vegetation composition as well as long-

12 term changes, and it can be used to infer future responses of vegetation to predicted

13 environmental change (Parmesan & Yohe 2003; Root et al. 2003; Peñuelas et al. 2007).

14 Vegetation dynamics in range margin communities are of particular interest. Species at

15 their distributional limits experience serious stress, and are therefore highly responsive

16 to abiotic environmental conditions (Lennon et al. 2002; Travis 2004), making range-

17 margin communities particularly sensitive to environmental change (Hoffmann &

18 Blows 1994; Case et al. 2005). Furthermore, changes at range margins are likely to be

19 the first steps in range-shifting, and are therefore of interest in determining to what

20 extent communities might respond as units during environmental change.

21   Here we examine patterns of vegetation dynamics (long-term trends and

22 interannual variation) over a 26-year period in a range-margin steppic community in

23 Central Germany. This community is at the western distributional limit for this

24 community type, being under the warmest and most humid (i.e. most oceanic)

25 conditions within its range. These steppic communities are xeric in nature, and long-

1   term data from xeric systems is particularly scant despite their potentially high

2   sensitivity to environmental change (WallisDeVries et al. 2002; Stadler et al. 2007).

3   Climate change has affected and is currently affecting ecosystems in many parts

4   of the world (Sala et al. 2000; Root et al. 2003; Menzel et al. 2006). However, while

5   most studies have focused on the impacts of global warming, other aspects of climate

6   such as rainfall patterns and the intensity and amount of solar radiation reaching the

7   Earth's surface have received far less attention (Meehl et al. 2005; Wild et al. 2005).

8   Furthermore, to understand long-term and interannual changes in vegetation and their

9   relationship to climate, it is essential to study responses at the community level, since

10   climate affects whole communities as well as individual species, and may have both

11   direct effects and indirect effects, the latter being mediated, for example, through

12   interactions between species (Dunnet & Grime 1999; Brooker 2006).

13   Certain species or functional groups have disproportionately large effects on

14   particular community characteristics, and climate responses of vegetation can be

15   specific to particular species (Peñuelas et al. 2002; Walther 2003) or functional groups

16   (Sternberg et al. 1999; Brooker & van der Wal 2003; Rodríguez et al. 2003; Morecroft

17   et al. 2004; Ingerpuu & Kupper 2007). Thus, if different species or functional groups

18   respond differently to climate drivers, key characteristics of plant communities such as

19   cover, species richness, and species composition might not respond to climate change in

20   a simple, easily predictable manner. Furthermore, although functional groups provide an

21   approach to simplifying vegetation responses, enabling easier extrapolation of

22   predictions when species-level information is not available (Arft et al. 1999), if species

23   responses within functional groups are not consistent, then functional groups become a

24   potentially misleading tool.

1   Within our systems we consider annuals and perennials to belong to different

2   functional groups. Previous studies in semiarid systems have shown consistency of

3   response to climate, and consistent impacts of these groups both with respect to plant

4   interactions and to community properties and processes (O'Connor & Roux 1995;

5   Holzapfel & Mahall 1999; Anderson & Inouye 2001). Thus it is reasonable to use them

6   as the focus of our analysis at the functional group level. We investigated the long-term

7   and interannual dynamics of our range-margin steppic grassland community at the

8   community, functional group and species level to identify the causes of long-term

9   temporal trends in community composition. Our study addressed the following

10   questions: 1. Is climate a strong driver of vegetation dynamics, including interannual

11   variation, in a range-margin steppic community? 2. Are there long-term trends in cover

12   and species richness in this community, and are these consistent across functional

13   groups and species within groups? 3. Can the long-term trends in plant community data

14   be related to variation in local climate over the last three decades?

15

16   **Methods**

17   *Study Site*

18   The study area is a relatively arid region near Halle, Central Germany (51º 35' N, 11º

19   50' E) at 120 m a.s.l. on porphyritic outcrops with shallow soils characterized by a

20   mosaic of natural and seminatural dry and semidry grasslands within an agricultural

21   landscape (Winkler & Klotz 1997a,b). Mean annual temperature for the 1979-2005

22   period was 9.4 ºC (range 7.1-11.5ºC), and mean annual rainfall was 478 mm for the

23   same period (range from 260 to 654 mm; Meteorological Station Bad Lauchstädt of the

24   Helmholtz Centre for Environmental Research – UFZ; 15 km away from the plots at the

25   same altitude and similar topography).

1   The community studied has an average cover of 15-50% on extremely shallow

2   (5-15 cm), dry, nutrient-poor and acidic soils (Schubert et al. 2001). It is a remnant of

3   the postglacial natural vegetation of the area (more than 10^4 years old) and covers small

4   areas of l0- l000 m^2 within a mosaic of different communities. The underlying substrate

5   creates harsh conditions for plant growth and water appears to be the most limiting

6   growth factor. The community is not managed, except for occasional grazing by sheep

7   (less than once per year). During periods of grazing off-take levels are extremely low:

8   grazers appear to concentrate on the more attractive and productive neighbouring

9   vegetation types that are found outside the porphyritic outcrops. The community is

10   relatively species-poor, with an average of 10 species per m^2 found regularly over the

11   26 years studied. The main constituent of the community is *Festuca glaucina* Vill.

12   (Poaceae), a long-lived, tuft-forming grass. Other species present include perennial

13   grasses and herbs such as *Thymus serpyllum* L. (Labiatae), *Koeleria macrantha*

14   (Ledeb.) J.A. Schultes (Poaceae), *Hieracium pilosella* L. (Compositae) or *Silene otites*

15   (L) Wib (Caryophyllaceae), and a number of spring ephemerals such as *Spergula*

16   *morisonii* Boreau (Caryophyllaceae) or biennials like *Centaurea stoebe* L (Compositae).

17   For a full species list see Appendix 1. For the rest of this manuscript "annuals" refers to

18   both true annuals and the biannual *C. stoebe*.

19

20   *Data collection*

21   In 1980, three permanent plots of 1m x 1m were established within the porphyritic

22   outcrop community and marked with metal sticks. Vegetation composition was then

23   recorded every year until 2005 (2001 and 2004 data are missing). All three plots were

24   located within a 10 m diameter circle. The total size of the outcrop was more than 500

25   m^2. The plots were recorded once every year in spring or early summer by the same

1	observer (Stefan Klotz). Each plot was sampled using a square grid of 100 cells 1 dm^2

2	in size , placed above the vegetation so disturbance due to sampling was minimal. The

3	number and size of all individuals was mapped each year.

4

5	*Correlations with climatic variables and statistical analyses*

6	Relationships between plant community variables and climatic data were assessed by

7	best-subset regression, a model-building technique which finds subsets of predictor(s)

8	variable(s) that best predict responses on a dependent variable by linear regression (Zar

9	1999), which is commonly used in detection of climate impact (e.g. Menzel 2003).

10	Temperature and precipitation data (monthly, 2- and 3-monthly means) of the recording

11	year (from January to measurement date) and the preceding year were used to build the

12	best single-predictor models. Plant community variables analysed were cover and

13	species richness of the community as a whole, and the same for individuals of

14	perennials (23 species) and annuals (11 species), as well as cover of the dominant

15	species, three perennial and two annual species (see below) that together represented

16	more than 80% of the plant cover.

17	To explore relationships between interannual variability of the plant community

18	and climate, vegetation and climate data were detrended to remove temporal trends and

19	autocorrelation, and interannual variation was then calculated from the residuals of each

20	variable (Legendre & Legendre 1998). Interannual variation of vegetation data was then

21	regressed against that of the climate data.

22	The existence of temporal trends in the composition and cover of the plant

23	community were tested by means of a General Linear Model (GLM) for each dependent

24	variable: cover and species richness for the full community and functional groups, with

25	plot as a categorical predictor and year as a continuous predictor, as well as separate

analyses for the dominant species. When the assumptions of the model (constant variance, normality and independence of the residuals) were not satisfied, the dependent variable was log-transformed to meet the assumption of constant variance of the residuals, and a lagged version of the dependent variable was used as a covariate to meet the assumption of independence of the residuals (i.e. to account for the autocorrelation of the residuals). We further explored species-level variation in cover through PCA analyses and linear regression of the cover of each species against time. Finally, the relationships among the dependent variables were tested with simple linear Pearson correlation.

Temporal trends in climatic variables were tested by fitting linear regressions of the climate data against time. Although the particular key climate variable may vary among species and may not be represented precisely by those used in our analysis, as climatic parameters are commonly strongly correlated, the climatic parameters used here are likely to give a reasonable representation of changes in the parameters for plant species. All statistical tests were considered significant at $P < 0.05$. All the analyses were performed with Statistica 6.0 (2004, StatSoft, Inc., Tulsa, OK USA).

Results

Mean total cover for the target community over the study period was 24.65 ± 1.02 % (mean ± standard error; ranging from 10 to 51%; n=72). Perennial species accounted for up to 90% of the total cover. A total of 34 plant species belonging to 15 families were recorded throughout the study. The most abundant perennial species in terms of cover were *Festuca glaucina, Hieracium pilosella* and *Koeleria macrantha*. The most abundant annual species were *Spergula morisonii* and *Centaurea stoebe*. The most abundant families were Compositae and Caryophyllaceae (both with 23%) followed by

1   Poaceae (17%). The average number of species found per year was 10 (ranging from 5

2   to 14), with 20% of them being annual species (see Appendix 1 for cover and frequency

3   values for each species).

4

5   *Relationships between climate and plant community data*

6   The best fit single-variable models of the relationships between climate and plant

7   community data were in all cases highly significant (Table 1) and generally accounted

8   for more than 50% of total variation.

9   The best climatic predictor for total cover and species richness was mean April

10   temperature (Table 1), with higher April temperatures associated with lower total cover

11   and species richness. The same was true for the cover of the perennial species, whilst

12   the number of perennials was most closely correlated with mean April-May temperature

13   and also showed a negative relationship. By contrast, the best climatic predictor for the

14   cover and number of annual species was May precipitation, which correlated positively

15   with these two variables. However, when the responses of the five dominant species

16   were examined, species-specific patterns were found that did not match functional-

17   group level patterns. For the perennials, while the cover of *F. glaucina* and *H. pillosela*

18   responded negatively to increasing April temperatures, *K. macrantha* responded

19   positively to December-January precipitation. April-May and September precipitation

20   were, respectively, the best predictors for the cover of the two most abundant annual

21   species, *S. morisonii* and *C. stoebe* (Table 1).

22   The relationships between interannual variation in plant community and climatic

23   data were also dependent on functional groups and individual species. Interannual

24   variability in autumn (September-November) temperature was the best predictor for the

25   interannual variability in both total cover and cover of the perennial species (Table 1).

1 Interannual variation in species richness and the number of perennial species was best

2 correlated with the interannual variability in April and April-May temperature,

3 respectively, concurring with the relationships found using the raw annual data.

4 Similarly, interannual variation in the cover and number of annual species correlated

5 with the interannual variation in April-May and spring (March-May) precipitation

6 (Table 1). At the species level, the best predictors for the interannual variation in the

7 cover of *F. glaucina* and *K. macrantha* were autumn and October-November

8 temperature, respectively. The interannual variation in the cover of *Hieracium pilosella*

9 was again correlated with interannual variation in April temperature. Finally, the

10 interannual variation in the two dominant annual species, *C. stoebe* and *S. morisonii,*

11 was best correlated with interannual variation in October-November temperature and

12 April-May precipitation.

13

14 *Temporal trends in plant community data*

15 Correlation of the response variables among plots was high over the study period (e.g.

16 ranging from 0.72 to 0.82), and we can therefore conclude that characteristics of the

17 three plots varied in a broadly similar manner. Furthermore, analysis of vegetation

18 temporal trends indicated no significant plot x year interactions (Tables 2 and 3), hence

19 all plots showed similar temporal patterns.

20 Total cover showed a significant (50%) decline during the study period (Table

21 2). The same trend was found for the cover of the perennial species, but cover of annual

22 species showed no significant trend (Table 2). However, contrasting responses were

23 again found for different species within functional groups (Table 3). Cover of the

24 perennials *F. glaucina* - the species that accounted for most of the community cover -

25 and *H. pillosela* declined significantly over time ($R = -0.44$, $P < 0.01$ and $R = -0.64$, $P <$

1   0.001, respectively). In contrast, cover of the perennial *K. macrantha* did not

2   significantly change over time. While cover of the annual *S. morisonii* decreased over

3   time (R = -0.42, P < 0.01), cover of the annual *C. stoebe* increased significantly (R =

4   0.62, P < 0.001; Table 3).

5   PCA analyses and linear regression of the cover of each species against time

6   highlighted three main groupings within those species occurring with sufficient

7   frequency to be included in the analysis: decreasing, constant and increasing species

8   (Fig. 1). These grouping did not entirely concur with our functional groups. Annual and

9   perennial species were present in both the constant and decreasing groupings. However,

10   only annual species were present within the increasing group and of these only *C.*

11   *stoebe* had substantial (but still limited) cover (Fig. 1 and Appendix 1).

12   There was no significant change in overall species richness through time (Table

13   2). Whilst there was a significant decrease in the number of perennial species, there was

14   a significant increase in the number of annual species (Table 2). Total cover was

15   positively and significantly correlated with both the cover (R = 0.98, P < 0.0001) and

16   number (R = 0.38, P = 0.001) of perennial species. However, cover and number of

17   annual species showed negative correlations with total cover (R = -0.23, P = 0.053 for

18   cover and R = -0.24, P = 0.034 for number of annual species).

19

20   *Temporal changes in climatic conditions*

21   During the period 1980-2005, mean annual temperature in our study area increased by

22   1.4ºC (based on predicted values from linear regression of temperature against time,

23   from 1980 to 2005, R = 0.38, P < 0.05). April temperature increased by 2.3 ºC (Fig. 2).

24   There was no significant change in autumn temperature. However, both mean annual

25   temperature and April and autumn temperature were positively correlated (R = 0.36, P <

1   0.05; $R = 0.58$, $P < 0.001$ respectively). Likewise, there were no significant changes in

2   annual precipitation ($R = 0.09$, $P = 0.65$), or in May precipitation ($R = -0.08$, $P = 0.94$;

3   Fig. 2) during the study period. May precipitation and annual precipitation were highly

4   correlated ($R = 0.63$, $P < 0.001$).

5

6   **Discussion**

7   As for the analysis of many long-term data series (Parmesan & Yohe 2003) this study is

8   inevitably correlative. However, there is strong evidence that interannual variability and

9   long-term changes in local climate played a significant role in plant community

10 dynamics. The relationships detected between climate drivers and vegetation can be

11 explained by the ecology of the key species. In general, annuals in these systems

12 germinate and grow in response to the favourable water balance in autumn and spring

13 (Winkler & Klotz 1997a,b), which concurs with our observed response of annuals to

14 rainfall. Perennials integrate the precipitation-temperature balance over the course of the

15 full year and may thus be more responsive to temperature, as observed. Despite these

16 common patterns, the five most abundant species showed species-specific variation in

17 climate responses regardless of their functional group. The highly significant

18 relationships detected between climate (particularly spring conditions) and plant

19 performance support the hypothesis that species within xeric range-margin communities

20 are highly responsive to changes in climate. Furthermore, these results highlight that

21 responses detected at the functional-group level may mask quite contrasting responses

22 within functional groups.

23   Analyses of interannual variation supported the proposed influence of climate on

24 vegetation in this system, particularly the role of spring conditions: interannual variation

25 in spring temperature (April or April-May) or precipitation (April-May or March-May)

1   was strongly related to interannual variability in many of the plant community variables

2   (e.g. species richness, number of perennial and annual species, cover of annual species

3   and cover of *Hieracium pilosella* and *Spergula morisonii*). However, autumn

4   temperatures had an important influence on total cover, cover of the perennials, and

5   cover of *Festuca glaucina*, *Koelleria macrantha* and *Centaurea stoebe*, concurring with

6   previous studies highlighting the importance of autumn conditions for the germination

7   of these species (Bruun et al. 2007; Winkler & Stöcklin 2002). Other studies have also

8   found that short-term or interannual climatic variability has a strong influence on plant

9   community dynamics and physiology (Peñuelas et al. 2007; Martínez-Alonso et al.

10   2007; MacDougall et al. 2008) and so it is reasonable to conclude that interannual

11   variation in climate is partly driving interannual variation in vegetation.

12   We also found long-term temporal trends in plant community variables, but

13   again functional group level responses appear to be masking species-specific effects.

14   The negative temporal trend in total cover of the community was driven in particular by

15   reductions in the cover of two dominant perennials – *F. glaucina* and *H. pilosella* - but

16   there was no significant long-term trend in cover of the third dominant perennial, *K.*

17   *macrantha*. Contrasting responses of the most abundant annual species (*S. morisonii*

18   and *C. stoebe*) led to no overall temporal cover trend for the annuals as a group. Thus,

19   long-term temporal changes in species richness were apparent only when the data were

20   analysed at the community or functional group level: perennial species number declined

21   significantly over time, whilst number of annual species showed a positive trend.

22   Factors like land use and pollution probably play a proportionately small role in

23   our study area. Land management activities and grazing are relatively unimportant

24   drivers because the community is not managed and livestock are rarely present on the

25   site. Neighbouring vegetation is more attractive to grazers and grazing is rare.

1   Furthermore, grazing - unless at very high levels - would lead to increased community

2   productivity and invasion of more competitive species (Milchunas & Lauenroth 1993):

3   in contrast we see a general long-term decline in cover in this system. On the other

4   hand, nitrogen deposition can directly influence the productivity and dynamics of

5   ecosystems (Bobbink 1998; Bobbink et al. 1998; van der Wal et al. 2003). However,

6   while local output of some pollutants decreased considerably after German reunification

7   (e.g. 86% decrease in particulates emissions from 1990 to 1999), increased transport

8   emissions and agricultural activity have largely maintained N deposition levels (e.g.

9   18% decrease in NH_4 deposition in the same period; Environmental data Germany,

10   http://www.umweltdaten.de). Reduced N deposition would favour slow-growing stress

11   tolerant species typical of the environment examined in our study (van der Wal et al.

12   2003), and is unlikely to have lead to the detected declines in species cover and

13   richness.

14   There is a considerable body of evidence indicating a primary role for water

15   availability in determining plant performance in xeric communities (Churkina et al.

16   1999; Sternberg et al. 1999; Zavaleta et al. 2003; Lloret et al. 2004). Increased

17   temperature could lead to reduced plant water availability even if it is not associated

18   with long-term decreases in precipitation (as in our case). Furthermore, solar radiation

19   may also influence water availability. This region experienced a significant increase in

20   solar radiation during the study period ($R = 0.85$, $P < 0.0001$; Fig. 2). Although contrary

21   to the well-known 'solar dimming' (Stanhill & Cohen 2001), this trend is consistent

22   with recent reports of a reversal from dimming to brightening during the 1990s in many

23   regions (Wild et al. 2005; Pinker et al. 2005) and substantial (86%) recent reductions in

24   particulate emissions in our region. To test for the combined impact of climate trends on

25   water availability, we calculated potential evapotranspiration (PET) values for typical

1   dry and wet days in the first and last two years of the study period using the Penman

2   calculator (http://www.tfrec.wsu.edu/Orchard/pET/pETCalc.html, Penman 1948). These

3   calculations show a possible 40-90% increase in PET (wet and dry April days

4   respectively, 0.5-2.0 mm in 1980-81 to 0.7-3.8 mm in 2004-2005) during this time.

5   Increased water stress is therefore likely to have contributed to the significant decrease

6   in total plant cover and cover of two of the dominant perennial species over the study

7   period. Similar findings were observed by Anderson & Inouye (2001) in sagebrush

8   steppe and by Morecroft et al. (2004) in temperate grassland systems. Although the

9   cover of the other three dominant species did not change significantly over the study

10   period, this is also consistent with climatic trends at this site: their success correlates

11   strongly with precipitation or autumn temperature, which showed no long-term

12   temporal trend.

13   We did not find a significant temporal trend in total species richness, but there

14   was a negative correlation of total species richness and its interannual variation with

15   April temperature. Previous studies have reported responses of community species

16   richness to changes in climate (Chapin et al. 1995; Dunnet et al. 1998; Zavaleta et al.

17   2003). Chapin et al. (1995) found that elevated temperature led to the loss of 30-50% of

18   species after 9 years in an arctic tundra community, and Stenberg et al. (1999) found a

19   significant decrease in species richness after winter warming in calcareous grassland.

20   However, these species losses were driven by expansion of dominant perennial species.

21   In our study perennial species and total cover declined over time. As adult perennial

22   species in xeric systems may produce favourable microclimatic conditions for

23   germination (Gomez-Aparicio et al. 2004; Maestre et al. 2005), both reduced adult

24   perennial plant cover and the direct negative effects of increased environmental severity

25   may limit seedling germination and establishment, increasing the chances of species

1   loss. However, the number of annual species showed a significant increase through

2   time, and 2 annual species were grouped together in our PCA analysis because of a

3   common trend toward increased cover through time. Annual species may be less

4   dependent on facilitation from perennials for germination – they germinate at times of

5   increased water availability. Additionally, decreasing cover of two perennials may be

6   enabling the establishment of annual species through reduced competition. This is

7   concluded by the negative correlations between total cover and either the cover or the

8   number of annuals species, providing evidence for the role of interactions between

9   species in mediating climate change impacts on plant communities (McCarthy 2001;

10   Fitter & Fitter 2002; Brooker 2006).

11   Interestingly, overall variation in the climate during the study period can be

12   attributed to both interannual variability and long-term climate trends. For example,

13   both April and autumn temperatures were positively correlated to mean annual

14   temperature. However, although April and annual temperatures showed a long-term

15   positive trend, autumn temperatures did not. This would suggest that long-term trends in

16   annual temperature are driven more strongly by changes in spring conditions, whilst

17   interannual variation is driven to a larger extent by autumn temperatures. Such patterns

18   are mirrored in the responses of the vegetation. For example, autumn temperatures

19   influenced interannual variation in the cover of perennials, but long-term negative

20   trends in perennial cover were associated with increasing spring temperatures. Such

21   results concur with previous studies showing that spring-time climatic conditions show

22   stronger long-term temporal effects as a result of climate change, and that plant

23   processes in spring result in stronger long-term climate change responses (Fitter &

24   Fitter 2002; Sparks & Menzel 2002).

1   In conclusion, despite the general decrease of cover and species richness with

2   rising temperatures, the various long-term trends and responses to climate found in this

3   study highlight the need for studies that adopt a hierarchical approach, i.e. that examine

4   responses at the community, functional group or growth form, and species levels. Long-

5   term responses are the result of both climatic and non-climatic factors (e.g. biotic

6   interactions), and different characteristics of a community - e.g. plant cover and species

7   richness - may respond to different climatic drivers in a complex, non-parallel manner.

8   We observed that there can be considerable variation in response within functional

9   groups, and that communities such as this are unlikely to respond as a whole to climatic

10   drivers. Future predictions of species responses to climate change must therefore

11   account for such variation.

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1 **Table 1**. Relationships between plant data and climatic variables, determined according

2 to best-subsets regression (see text for details). Top: Relationships between total plant

3 cover and species number, cover and number of perennial and annual species, and cover

4 of the five most dominant species with climatic variables. Bottom: Relationships

5 between the interannual variation of each dependent variable and the interannual

6 variation in climate. *R* coefficient, sign and significance are shown for each relationship;

7 * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

8

Raw data		
Variable	**Best climatic predictor**	***R***
Total Cover (TC)	Mean April Temperature	-0.56***
Species richness (SR)	Mean April Temperature	-0.39***
Cover of Perennial Species (CP)	Mean April Temperature	-0.54***
Number of Perennial Species (NP)	Mean April-May Temperature	-0.46***
Cover of Annual Species (CA)	May Precipitation	0.50***
Number of annual species (NA)	May Precipitation	0.43***
Festuca glaucina (F. g.)	Mean April Temperature	-0.31***
Hieracium pillosela (H. p.)	Mean April Temperature	-0.56***
Koeleria macrantha (K .m.)	December-January Precipitation	0.60***
Spergula morisonii (S .m.)	April-May Precipitation	0.50***
Centaurea stoebe (C .s.)	September Precipitation	0.41***
Interannual variation data		
Variable	**Best climatic predictor**	***R***
TC Interannual variation	Autumn (Sept.-Nov.) Temp. Interannual variation	-0.54***
SR Interannual variation	April Temp. Interannual variation	-0.44***
CP Interannual variation	Autumn Temp. Interannual variation	-0.56***
NP Interannual variation	April-May Temp. Interannual variation	-0.51***
CA Interannual variation	April-May precipitation Interannual variation	0.47***
NA Interannual variation	Spring precipitation Interannual variation	0.40***
F. g. cover Interannual variation	Autumn Temp. Interannual variation	-0.70***
H. p. cover Interannual variation	April Temp. Interannual variation	-0.32*
K. m. cover Interannual variation	Oct.-Nov. Temp. Interannual variation	-0.47***
S. m. cover Interannual variation	April-May precipitation Interannual variation	0.50***
C. s. cover Interannual variation	Oct.-Nov. Temp. Interannual variation	0.30**

1　**Table 2.** Results of the General Linear Model (degrees of freedom, F and p values) for

2　temporal trends in total cover, cover of perennial and annual species, total species

3　richness and number of perennial and annual species. Variables with an asterisk were

4　log-transformed and a lagged version of the variable was added to satisfy the

5　assumptions of the model. Temporal trends over the study period − negative (-), non-

6　significant (N.S.), and positive (+) – are also shown.

7

Variable	Source of Variation	Degrees of freedom	F	P	Temporal trend
Total Cover	Plot	2	12.0212	**<0.0001**	
	Year	1	33.5183	**<0.0001**	**-**
	Plot x Year	2	2.5184	0.0883	
	Residuals	66			
Cover of Perennial Species	Plot	2	8.6345	**<0.0001**	
	Year	1	29.3666	**<0.0001**	-
	Plot x Year	2	2.7845	0.0690	
	Residuals	66			
Cover of Annual Species *	Plot	2	0.4586	0.6341	
	Year	1	0.8247	0.3670	N.S.
	Plot x Year	2	2.4263	0.0962	
	Residuals	66			
Total Species Richness	Plot	2	0.441	0.6450	
	Year	1	0.348	0.5571	N.S.
	Plot x Year	2	1.555	0.2188	
	Residuals	66			
Number of Perennial Species	Plot	2	0.064	0.9382	
	Year	1	6.829	**0.0110**	-
	Plot x Year	2	1.275	0.2862	
	Residuals	66			
Number of Annual Species	Plot	2	1.0356	0.3607	
	Year	1	10.3938	**0.0019**	+
	Plot x Year	2	0.8296	0.4407	
	Residuals	66			

8

9

10

1 **Table 3.** Results of the General Linear Model (degrees of freedom, F and *p*-values) for

2 temporal trends in the cover of the dominant species. Variables with an asterisk were

3 log-transformed and a lagged version of the variable was added to satisfy the

4 assumptions of the model. P = Perennial, A = Annual. Selected species accounted for

5 80% of total cover in the plant community. Temporal trends over the study period -

6 negative (-), non-significant (N.S.), and positive (+) – are also shown.

7

Variable	Source of Variation	Degrees of freedom	F	*P*	Temporal trend
Festuca glaucina (P)	Plot	2	1.22436	0.3005	
	Year	1	9.97116	**0.0023**	-
	Plot x Year	2	1.22132	0.3014	
	Residuals	66			
Hieracium pilosella (P)	Plot	2	12.52774	**<0.0001**	
	Year	1	7.72193	**0.0071**	-
	Plot x Year	2	6.25013	0.1331	
	Residuals	66			
Koeleria macrantha (P)	Plot	2	20.1945	**<0.0001**	
	Year	1	0.0154	0.9015	N.S.
	Plot x Year	2	9.3088	0.275	
	Residuals	66			
Spergula morisonii (A)	Plot	2	0.999551	0.3735	
	Year	1	7.727734	**0.0070**	-
	Plot x Year	2	0.989174	0.3773	
	Residuals	66			
*Centaurea stoebe** (A)	Plot	2	2.51165	0.0888	
	Year	1	31.03772	**<0.0001**	+
	Plot x Year	2	2.52746	0.0875	
	Residuals	66			

8

Figure 1. Principal component analysis (PCA) of species cover over the study period. The average cover of the species in the three plots in each year was used in the analysis. Extremely infrequent species, i.e., those appearing less than 3 years in the 26-years study, were excluded. Different patterns indicate different temporal trends of the species according to linear regression against time (empty circle, species increasing over time; light grey, species decreasing over time; dark grey, constantly present species). The combined results of the PCA and linear regressions were used to group the species (see Appendix 1) according to their temporal trend.
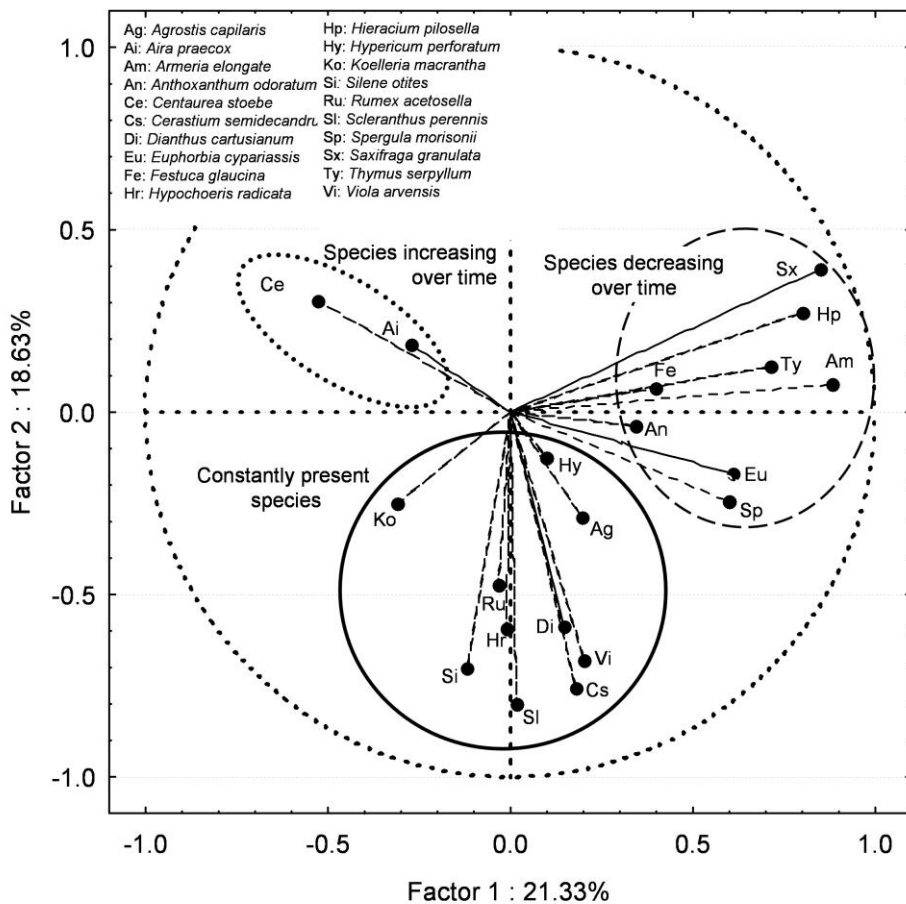
Figure 2. Trends for climatic variables in the study area (measured in Meteorological Station Bad Lauchstädt of the UFZ-Centre for Environmental Research Leipzig-Halle) during the period of study. Mean April temperature (upper left), Mean April-May temperature (upper right), May precipitation (middle left), Autumn temperature (middle right) and annual cumulative solar radiation (bottom left). * $P < 0.05$, ** $P < 0.01$, P *** < 0.001, N.S., non significant.
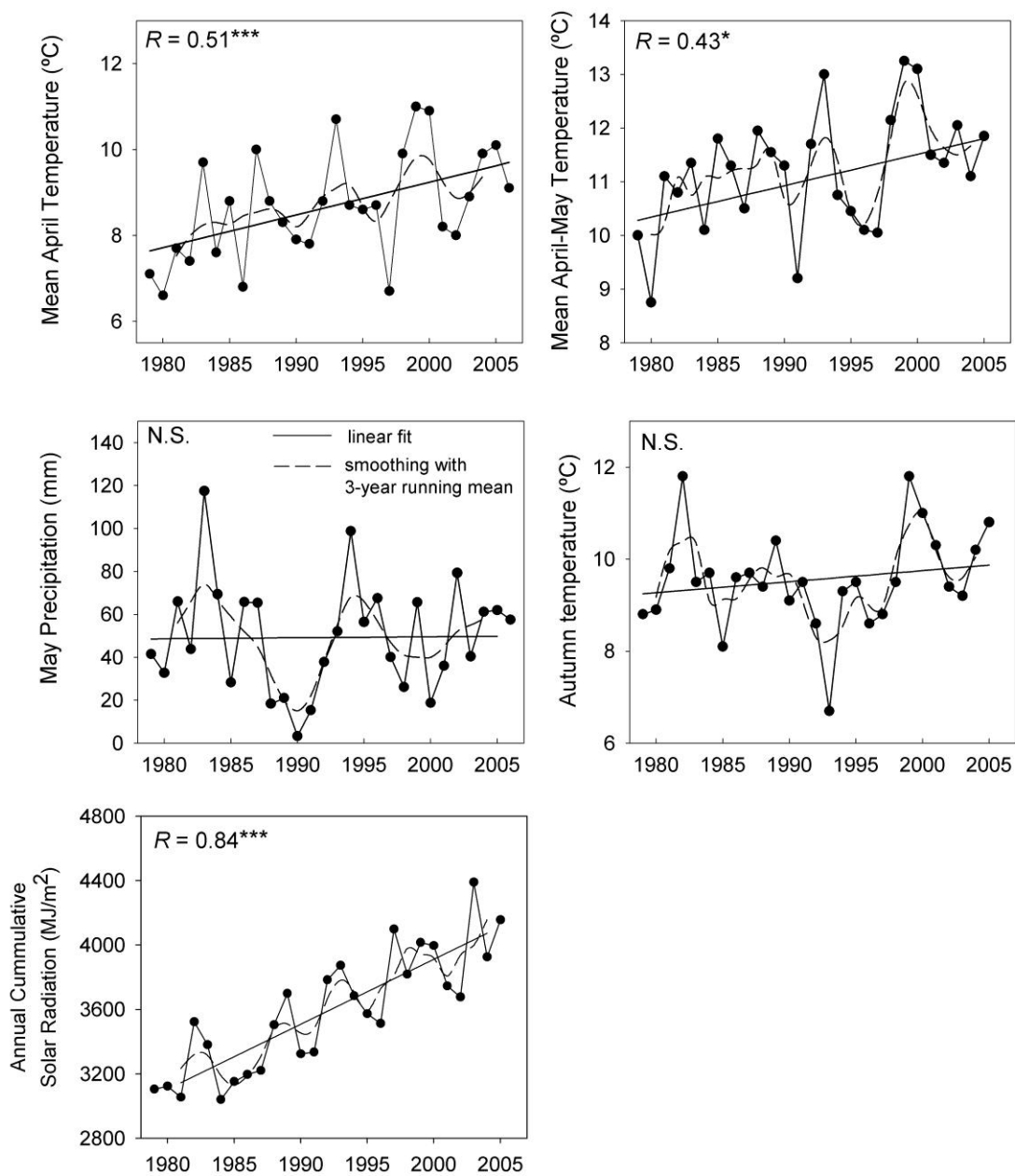
Appendix 1. Percentage of each species in each plot and year. Species are grouped in relation to temporal trends over the study period following linear regression and PCA analysis (Fig. 1). RG= PCA and regression response group, CD=Common species decreasing, RD=Rare species decreasing, CI=Common species increasing, RI=Rare species increasing, Con=Constant over time, EI=Extremely infrequent species (excluded from PCA analysis). FG=Functional group, A=Annual (including the biannual *C. stoebe*), P=Perennial. Total cover, percentage of bare soil, and number of species are also shown.

PLOT 1

Species	RG	FG	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	2005
Festuca glaucina	CD	P	16.2	14.59	22.71	14.89	19.49	19.84	20.56	14.23	20.74	17.46	12.3	15.65	14.56	17.36	14.71	8.32	9.05	8.66	9.94	14.78	13.49	13.14	14.64	6.51
Hieracium pilosella	CD	P	13.01	0.39	0.18	0.15	0.18	1.02	1.05	0.06	0.18	0.12	0	0	0	0.09	0.39	0.24	0.27	0.69	0.87	0.57	0.09	0.75	1.23	0.27
Euphorbia cypariassis	CD	P	0.9	1.82	6.31	1.8	1.99	1.55	1.98	1.23	2.63	3.11	2.28	2.69	0.1	0.15	0.1	0.1	0.3	0.35	0.3	0.3	0.07	0.602	0.23	0.73
Spergula morisonii	RD	A	0	0	0.15	2.98	0.1	1.4	0.1	0	0	0	0.008	0.3	0.103	0.202	0.001	0.037	0.004	0.077	0.01	0.014	0.002	0.112	0.06	0
Anthoxanthum odoratum	RD	P	0	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armeria elongata	RD	P	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0
Saxifraga granulata	RD	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serpillum	RD	P	1.8	0	0	0	0	0	0.2	0	0.15	0	0	0.1	0	0	0	0.001	0	0	0	0	0	0.006	0.05	0
Centaurea stoebe	CI	A	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4	1.14	0.95	2.4	1.98	0.02	0.24	0.56	1.33	1.33	2.38
Aira praecox	RI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0
Cerastium semidecandrum	Con	A	0	0.014	0	0.001	0.001	0	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis capilaris	Con	P	0.25	0	0.5	0	0.65	2.15	2.55	1.16	2.55	1.55	0.75	2.67	1.35	1.4	6	0.52	0.1	0.17	0.35	0	0.15	0.45	0.3	0.37
Dianthus cartusianum	Con	P	0.2	0	0	0.95	1.05	0.65	1	1.4	1.6	1.66	1.33	0.53	0.001	0.2	0.001	0	0	0	0	0	0	0	0	0.02
Hypericum perforatum	Con	P	0	0	0	0	0.25	0.1	0.151	0	0.4	0.15	0.1	0.05	0	0	0	0.102	0.2	0.22	0	0	0.001	0.3	0.15	0
Hypochoeris radicata	Con	P	0	0	0	0.15	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koelleria macrantha	Con	P	1.7	1.6	2.05	1.65	4.93	4.83	6.27	5.85	7.64	7.16	4.33	4.61	3.853	4.33	4.7	1.398	1.1	0.83	1.55	1.33	1.62	1.733	2.03	1
Silene otites	Con	P	0	0	0	0	0.8	0.95	1.15	1.13	1.08	1.3	1.66	1.97	1.2	0.98	0.5	1.38	0.43	0.05	0.4	0.001	0	0	0	0
Rumex acetosela	Con	P	0	0	0	0	1.1	1.58	0.1	0	0	0	0	0.6	0.002	0.002	0.2	0.017	0	0	0	0	0.9	0	0	0
Viola arvensis	Con	A	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0.001	0	0	0
Scleranthus perennis	Con	P	0	0	0	0	1.3	0	0	0	0	0	0	0.11	0	0	0	0	0	0	0	0	0	0.2	0.15	0
Erophila verna	EI	A	0.009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campanula rotundifolia	EI	P	0.88	0	0	1.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gallium sp.	EI	P	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactuca serriola	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
Myosotis stricta	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
Scleranthus annus	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
Senecio vernalis	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achillea millifolia	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0.05	0	0	0	0
Luzula campestris	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata	EI	P	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa sp.	EI	P	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taraxacum officinalis	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0
Arenaria serpyllifolia	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0.15	0	0	0	0	0	0	0	0	0.272	0.18	0
Bare soil (%)			64.75	81.35	68.1	75.85	68.01	65.93	64.79	74.94	63.03	67.39	77.24	70.72	78.58	74.69	72.26	86.74	86.14	86.98	86.56	82.71	84.02	80.1	79.45	88.72
Total Cover (%)			35.25	18.65	31.9	24.15	31.99	34.07	35.21	25.06	36.97	32.61	22.76	29.28	21.42	25.32	27.74	13.26	13.86	13.02	13.44	17.29	15.98	19.9	20.55	11.28
N. of species			11	7	6	9	13	10	13	7	9	9	8	11	10	11	10	15	9	9	8	8	9	14	12	7

PLOT 2

Species	RG	FG	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	2005
Festuca glaucina	CD	P	15.11	15.64	19.68	7.89	11.41	12.59	15.8	11.85	17.02	17.1	12.11	11.23	10.73	16.7	19.15	11.43	9.61	11.61	12.89	13.11	10.09	14.89	19.28	3.94
Hieracium pilosella	CD	P	5.3	0.21	0.66	0.12	1.23	1.89	2.85	1.08	2.16	0.99	0.48	0.42	0.15	0.6	2.52	0.96	0.66	1.68	3.09	3.3	2.31	3.72	6.04	0.69
Euphorbia cypariassis	CD	P	0.7	0.29	1.5	0	0.25	0.2	0.35	0.28	0.35	0.11	0.23	0.1	0	0	0	0.05	0	0.13	0.12	0.1	0.1	0	0.8	1.81
Spergula morisonii	RD	A	0	0	0.9	7.12	6.55	1.447	0.563	0.35	0.702	0.45	0.013	3.71	0.939	0.26	0.002	0.023	0.005	0.039	0.011	0.031	0	0.231	0.04	0
Anthoxantus odoratum	RD	P	0	1.401	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armeria elongate	RD	P	0.1	0.25	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga granulata	RD	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serpillum	RD	P	4.1	0.23	0.15	0	0.03	0.1	0.25	0.8	1.15	0.83	1.43	1.45	0	0	0	0	0	0	0	0	0	0	0	0
Centaurea stoebe	CI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	1.1	0.89	1.49	0.06	0.24	0.2	0.86	0.73	0.21
Aira praecox	RI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.063	0	0	0
Cerastium semidecandrum	Con	A	0	0.009	0	0.003	0	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis capilaris	Con	P	2.8	0	5.5	0	0.91	4.45	6.15	3.57	5.5	0.75	0.4	0.75	0.3	0.65	2.45	1.61	1.12	2.81	1.5	0.62	0.25	1.2	2.3	1
Dianthus cartusianum	Con	P	0.2	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0.1	0.001	0.1	0.15	0	0.3	0.2	0.15
Hypericum perforatum	Con	P	0	0	0	0	0	0.05	0.001	0.13	0	0	0	0	0	0	0	0	0.2	0.23	0.053	0.001	0.15	0.601	0.1	0.2
Hypochoeris radicata	Con	P	0	0	0	0.2	0.77	0.85	0	0	0.55	0	0	0	0	0	0	0.401	0.1	0.001	0	0.003	0	0	0	0
Koelleria macrantha	Con	P	0.7	0.752	0.7	0.2	0.001	0.65	1.55	1.15	1.75	0.63	1.05	0.86	0.55	1.45	1.85	0.547	0.25	0.4	0.85	0.4	0.4	1.45	1.1	0.65
Silene otites	Con	P	0	1.15	1.35	0.85	0.35	1.1	0.55	0.48	0.4	0.53	0.33	0.481	0.05	0.2	0	0.75	0.2	0.2	0.2	0.701	0.3	0.7	0	0
Rumex acetosela	Con	P	0	0	0	0	0	0	0	0	0	0	0.1	0.772	0	0	0	0.102	0	0	0	0	0	0	0	1.38
Viola arvensis	Con	A	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scleranthus perennis	Con	P	0	0	0	0	0.4	0	0	0.65	0	0	0	0.53	0	0	0.15	0	0	0	0	0	0	0	0	0
Erophila verna	EI	A	0.055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campanula rotundifolia	EI	P	2.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gallium sp.	EI	P	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactuca serriola	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis stricta	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scleranthus annus	EI	A	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio vernalis	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achillea millifolia	EI	P	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luzula campestris	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0
Plantago lanceolata	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa sp.	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taraxacum officinalis	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0
Arenaria serpyllifolia	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.063	0	0
Bare soil (%)			68.39	80.07	69.16	83.62	78.1	76.67	71.94	79.66	70.41	78.61	83.86	79.7	87.28	80.14	73.63	83.03	86.87	81.41	81.13	81.34	86.2	75.94	69.41	89.97
Total Cover (%)			31.62	19.93	30.84	16.38	21.9	23.33	28.07	20.34	29.59	21.39	16.14	20.31	12.72	19.86	26.37	16.97	13.13	18.59	18.88	18.66	13.8	24.06	30.59	10.03
N. of species			11	10	10	7	10	10	10	10	10	8	9	10	7	6	7	11	10	11	10	11	8	11	10	9

PLOT 3

Species	RG	FG	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	2005
Festuca glaucina	CD	P	16.75	18.89	28.35	5.84	9.39	10.92	14.91	12.36	22.06	18.38	17.92	19.28	17.35	20.4	23.55	12.3	9.23	13.47	13.54	16.51	13.3	14.25	18.04	5.07
Hieracium pilosella	CD	P	15.05	14.64	13.05	1.83	5.4	12.3	4.71	3.3	4.71	3.75	4.29	3.12	0.36	0.51	1.83	1.02	0.48	0.87	1.77	2.64	2.85	5.49	4.71	5.96
Euphorbia cypariassis	CD	P	0.73	0.3	1.15	0.4	0.82	1.15	0.402	0.45	1.4	0.42	0.15	0.15	0.1	0.18	0.07	0.04	0.65	1.34	0.81	0.35	0.07	0	0	0.79
Spergula morisonii	RD	A	0	0	0.302	7.776	0.1	0.11	0.006	0	0.95	0	0	0.1	0.09	0.016	0	0.014	0.008	0.003	0.008	0.012	0.003	0.007	0.005	0
Anthoxantus odoratum	RD	P	0	0	0	0	0.25	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armeria elongate	RD	P	1.7	1.751	1.7	1.5	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga granulata	RD	P	0.15	0.15	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serpillum	RD	P	0.75	0.15	0.8	0	0.25	0.68	0.25	0	0	0	0	0.15	0	0	0	0.001	0	0	0	0	0	0	0.15	0
Centaurea stoebe	CI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	2	1.98	1.33	0.37	0.13	0.37	1.6	0.25	0.01
Aira praecox	RI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.003	0	0	0
Cerastium semidecandrum	Con	A	0	0.071	0.015	0.037	1.7	0.01	0.019	0.001	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0
Agrostis capilaris	Con	P	1.85	1.15	3.7	1.42	4.88	8.16	15.95	7.93	17.38	3.23	0.58	0.6	0.1	0.2	1.3	0.21	0.66	1.83	0.79	0	0.1	0.1	0.1	0.22
Dianthus cartusianum	Con	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum perforatum	Con	P	0	0.5	0.78	0	0.35	0.451	0.252	0.15	0.801	0.2	0.18	0.1	0	0	0	0	0.15	0.3	0.2	0.15	0.1	0	0	0
Hypochoeris radicata	Con	P	0	0	0	0	0.4	0.15	0.001	0	0	0	0	0	0	0	0	1.551	0	0	0	0	0	0	0	0
Koelleria macrantha	Con	P	0	0.35	0.8	0	0.751	1.1	2.05	2.051	2.3	2.8	1.13	1.75	2.456	4.6	5.58	1.813	2.1	1.081	2.81	3.52	2.71	3.81	4.251	1.55
Silene otites	Con	P	0.75	0.2	0	2.04	2.67	0.93	1.38	1.1	1.06	2.11	1.3	3.153	1.85	2.35	1.1	0.65	0.84	0.55	0.35	0.45	0.45	1.2	1.5	1.65
Rumex acetosela	Con	P	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.002	0.001	0	0	0	0	0	0	0	0
Viola arvensis	Con	A	0	0	0	0.801	0.85	0	0.011	0	0	0.005	0	0	0	0	0	0	0	0	0	0.101	0	0	0	0
Scleranthus perennis	Con	P	0	0	0	0	1.16	0	0	0.007	0	0	0	0.355	0	0	0.1	0.97	0.202	0.003	0	0	0	0	0	0
Erophila verna	EI	A	0.517	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Campanula rotundifolia	EI	P	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gallium sp.	EI	P	1.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactuca serriola	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis stricta	EI	A	0	0	0	0	0	0	0	0	0	0.103	0	0	0	0	0	0.102	0	0	0	0	0	0	0	0
Scleranthus annus	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio vernalis	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
Achillea millifolia	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0	0	0	0
Luzula campestris	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0
Plantago lanceolata	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa sp.	EI	P	0	0	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taraxacum officinalis	EI	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0
Arenaria serpyllifolia	EI	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0
Bare soil (%)			59.8	61.85	49.22	78.35	70.13	62.29	60.06	72.65	49.34	69	74.45	71.14	77.69	71.74	66.39	79.32	83.7	79.23	79.36	75.82	80.05	73.49	71	84.75
Total Cover (%)			40.2	38.15	50.78	21.65	29.87	37.71	39.94	27.35	50.66	31	25.55	28.86	22.31	28.26	33.61	20.68	16.3	20.77	20.65	24.19	19.96	26.51	29	15.25
N. of species			11	11	11	9	15	13	12	9	8	9	7	11	7	7	8	14	12	10	10	11	9	10	8	7