Man and Biosphere (MAB)

Evaluating the zonation of the Biosphere Reserve Wienerwald: How well does the conservation zone contribute to biodiversity conservation?

Final Report

Wolfgang Willner, Dietmar Moser, Karl Hülber, Norbert Sauberer,
Markus Staudinger & Viktoria Grass

Vienna, May 2017

Man and Biosphere (MAB)

Evaluating the zonation of the Biosphere Reserve Wienerwald: How well does the conservation zone contribute to biodiversity conservation?

Final Report

PD Dr. Wolfgang Willner (project leader), Dr. Dietmar Moser, PD Dr. Karl Hülber, Dr. Norbert Sauberer

V.I.N.C.A. – Institut für Naturschutzforschung und Ökologie GmbH
Vienna Institute for Nature Conservation and Analyses
Gießergasse 6/7
1090 Wien

Mag. Markus Staudinger, Dr. Viktoria Grass

AVL – ARGE Vegetationsökologie & Landschaftsplanung GmbH
Technisches Büro für Landschaftsökologie
Theobaldgasse 16/4
1060 Wien

ISBN 978-3-7001-8136-1
DOI: 10.1553/mab_biosphere_wienerwald

Austrian Academy of Sciences

Vienna, May 2017

Zusammenfassung

Wiesen, Trockenrasen und kleinstrukturierte Agrarlandschaften stellen einen integralen Teil des Biosphärenparks Wienerwald dar. Die Abgrenzung der Pflegezonen wurde 1994 nach dem damaligen Stand des Wissens, basierend auf sehr inhomogen vorliegenden Daten und ohne Erhebungen im Freiland, durchgeführt. Im Rahmen des vorliegenden Projekts standen drei Fragen im Mittelpunkt: (1) Gibt es signifikante Unterschiede bezüglich der Biodiversität und naturschutzfachlichen Bedeutung von Wiesenflächen inner- und außerhalb der Pflegezone? (2) Unterscheiden sich Lebensraumvielfalt inner- und außerhalb der Pflegezone? (3) Führten Änderungen in der landwirtschaftlichen Praxis in den letzten Jahrzehnten zu einer Veränderung der Biodiversität der Wiesen im Biosphärenpark Wienerwald, und, wenn ja, was sind die praktischen Implikationen für das Management dieser Flächen?

Wir verglichen Artenzahl und Zahl der Rote-Liste-Arten auf Flächen innerhalb (N = 534) und außerhalb (N = 215) der Pflegezone. Dieser Vergleich wurde sowohl mit dem Gesamtdatensatz als auch separat für einzelne Wiesentypen durchgeführt. Die Lebensraumvielfalt wurde anhand der bis Ende 2012 vorliegenden Daten der Offenlandkartierung untersucht. Hierzu wurden Testflächen mit einem Radius von 200 m innerhalb und außerhalb der Pflegezone zufällig ausgewählt. Für jede Fläche wurde die Anzahl der Biotoptypen, der Shannon-Wiener Diversity Index der Biotope, die Anzahl der FFH-Lebensraumtypen sowie der Flächenanteil der FFH-Lebensräume bestimmt. Weiters berechneten wir die insgesamt kartierte Fläche von ausgewählten Biotoptypen sowie den Grad der Abdeckung durch die Pflegezone.
Zur Untersuchung der zeitlichen Veränderungen wurden zwei Testgebiete mit gut verortbaren Vegetationsaufnahmen aus den Jahren 1990 bzw. 1992 ausgewählt und insgesamt 105 Aufnahmen wiederholt. Wir verglichen die historischen und aktuellen Vegetationsaufnahmen hinsichtlich Gesamtdeckung, Artenzahl und Zahl der Rote-Liste-Arten. Außerdem klassifizierten wir die Flächen nach der Art der Bewirtschaftung (AB: Brache, CO: konventielle Nutzung, OP1: eine ÖPUL-Periode, OP2: mind. zwei ÖPUL-Perioden). Veränderungen der mittleren Ellenberg-Zeigerwerte wurden mittels PCA und ANOVA getestet.

Im Durchschnitt zeigten Flächen innerhalb der Pflegezone eine höhere Artenvielfalt und wiesen mehr Rote-Liste-Arten auf als Flächen außerhalb der Pflegezone. Auch die Lebensraumvielfalt erwies sich innerhalb der Pflegezone als signifikant höher. Allerdings deuten die Ergebnisse klar darauf hin, dass sich eine beträchtliche Zahl von naturschutzfachlich wertvollen Flächen derzeit nicht in der Pflegezone befindet. Für drei Wiesentypen lag die mittlere Artenvielfalt außerhalb der Pflegezone sogar über jener innerhalb. Eine Reihe von naturschutzfachlich prioritären Wiesentypen sind derzeit nur zu etwa 3/4 ihres Gesamtbestands von der Pflegezone abgedeckt.
Die Wiederholung der Vegetationsaufnahmen aus den Jahren 1990/92 ergab eine deutliche Abnahme der Artenvielfalt wie auch der Zahl der Rote-Liste-Arten innerhalb der letzten 20 Jahre. Die Flächen zeigten insgesamt eine Verschiebung hin zu höheren Stickstoff- und Feuchtezahlen. Auf verbrachten Flächen nahm außerdem die Lichtzahl deutlich ab. ÖPUL verlangsamt diesen allgemeinen Trend zur Nutzungsaufgabe auf der einen und Intensivierung auf der anderen Seite zwar, doch konnte selbst auf Flächen, welche für mind. zwei Perioden an ÖPUL teilnahmen, der Verlust an Biodiversität nicht gänzlich aufgehalten werden. Der wichtigste Effekt von ÖPUL scheint demnach zu sein, Wiesen überhaupt in der Nutzung zu behalten. Für den Schutz der besonders wertvollen Flächen wird man aber zu alternativen Maßnahmen greifen müssen, welche eine stärkere Erfolgskontrolle, z.B. Zahlung in Abhängigkeit vom Ergebnis, beinhalten.

Summary

Meadows, dry grasslands and small-scale agricultural landscapes form an essential part of the so-called conservation zone of the Biosphere Reserve Wienerwald. The delimitation of the conservation zone was done in 2004, based on available data as well as on recommendations of a local advisory board but without field work. In this project, we addressed the following questions: (1) Are there significant differences in the biodiversity and conservation value of meadows inside and outside the conservation zone in the Biosphere Reserve Wienerwald? (2) Do areas inside and outside the conservation zone differ in habitat diversity and composition? (3) Did changes in agricultural land use practices affect the biodiversity of meadows in the Biosphere Reserve Wienerwald, and what are the implications for management and conservation of grasslands?

We compared species numbers and numbers of red list species of plots from inside (N = 534) and outside (N = 215) of the conservation zone. In addition to the overall difference we compared these parameters also separately for individual grassland types. For comparing habitat diversity and composition, we used data of the biotope mapping of the biosphere reserve. We randomly selected test circles with 200 m radius inside and outside the conservation zone. For each circle, we calculated the number of biotope types, the Shannon-Wiener Diversity Index of biotopes, the number of Natura 2000 habitat types and the percentage of area covered by Natura 2000 habitats. Moreover, we calculated the total mapped area of selected habitat types inside and outside the conservation zone and the portion of the total area of the habitat that is located within the conservation zone. To evaluate changes in the biodiversity of meadows within the last 20 years, we selected two test areas for which a sufficient number of relevés older than 15 years was available and for which the sampling site could be located with ± 5 m precision. 105 sites were re-sampled in 2011. We compared the historic and recent relevés in respect of species richness (number of vascular plant species), total cover, number of endangered species and their proportion on the total species richness. Moreover, we classified the sites according to the duration of management within the framework of the Austrian Agri-environmental Programme (ÖPUL). Changes of mean Ellenberg indicator values were tested using PCA and ANOVA.

On average, grassland plots inside the conservation zone had a higher species richness than plots outside, both with respect to the overall number of vascular plant species and the number of red list species. Habitat diversity was also significantly higher inside the conservation zone. However, our results revealed that there is a considerable number of valuable grasslands currently not covered by the conservation zone. Three grassland types showed even higher species richness outside the conservation zone. For several grassland types of high conservation priority, only 3/4 of their total area within the biosphere reserve is presently included in the conservation zone.

The re-sampling of plots revealed a considerable loss in overall species richness as well as in the number of endangered species. All plots showed a shift towards increasing Ellenberg indicator values for nutrients and moisture while abandoned sites showed an additional decrease in light values. ÖPUL measures decelerated the effects of this overall trend of abandonment on the one hand and intensification on the other hand but even in sites which have been included in the agri-environmental scheme for at least ten years, the biodiversity loss could not be completely stopped. The most important effect of ÖPUL is probably to maintain the management of meadows which otherwise would have been abandoned. For the future, switching to a “payment by result” approach might be a better strategy to preserve the most valuable grasslands within the biosphere reserve.

Contents

Introduction

Extensively used meadows and dry grasslands are the natural habitat of a substantial part of regional biodiversity in lower Austria and Vienna (Schön 2003, Wiesbauer 2008). The Biosphere Reserve Wienerwald, in particular those parts adjacent to the Pannonian lowland, represents a hotspot of species diversity as well as of habitat diversity (Niklfeld et al. 2008, Essl et al. 2008). Non-forest ecosystems play a fundamental role for tourism, recreation, local economy and biodiversity. As meadows and dry grasslands are man-made habitats, their conservation status is influenced by a complex interaction of natural and socio-economic processes (e.g. Zechmeister et al. 2003, Kuussaari et al. 2009, de Snoo et al. 2013).

The majority of meadows within the Biosphere Reserve Wienerwald are still extensively used and support an astonishing diversity of plant and animal species both at small and large scale. In 2007–2008, nearly 500 meadows within the Biosphere Reserve owned by the Austrian Federal Forest Authority (ÖBf) were mapped (Pfundner & Sauberer 2009). More than 700 plant species have been found in these meadows, and 10% of them (70 species) are endangered in Austria. Thus, the diversity and conservation value of the meadows is very high in comparison with other areas in Austria.

Meadows, dry grasslands and small-scale agricultural landscapes form an essential part of the so-called conservation zone (buffer zone) of the biosphere reserve. The delimitation of the conservation zone was done in 2004 on a scale of 1:50.000, based on available data (e.g. aerial photographs) as well as on recommendations of a local advisory board, but without field work. This led to the assignment of about 14% of the total area of the biosphere reserve as conservation zone (Becker et al. 2004). The conservation zone is not a large contiguous area but is divided into many, often quite small areas. This is not a methodological artifact but reflects the mosaic pattern of forests and open land which is typical for the Vienna Woods.

Due to limited human and financial resources, future management and conservation efforts will be focused on the conservation zone. However, preliminary results from mapping projects showed that not all meadows and agro-ecosystems of high conservation value are located within the conservation zone. Although the delimitation was the result of an objective and transparent process, it only reflects the level of information available at the time of the above mentioned study. At present, we do not know if the biodiversity and conservation value of non-forest ecosystems inside and outside the conservation zone are significantly different. For other protected areas, some studies have cast doubt on this issue (e.g. Caro 2001) or provided mixed results (Figueroa & Sanchez-Cordero 2008). If biodiversity and conservation value is not much different inside and outside the conservation zone, adjustments of the actual delimitation of the zones would be advisable.

One of the important biodiversity-related factors within the biosphere reserve is the changing agricultural land use practice. For many centuries, small-scale farms with a mixed livestock prevailed in the Wienerwald area. Presently, however, increasing size of management units goes hand in hand with special emphasis on horse keeping and cattle. These practices could significantly change the conservation value of meadows, but no evaluation of this issue has been done so far for the Biosphere Reserve Wienerwald.

The objective of this project was to evaluate the delimitation of the conservation zone in the Biosphere Reserve Wienerwald, and to identify trends of biodiversity change in semi-natural habitats which might have implications for the management and conservation of the grasslands in the Vienna Woods.

More specifically, we addressed the following questions:

1. Are there significant differences in the biodiversity and conservation value of meadows inside and outside the conservation zone in the Biosphere Reserve Wienerwald?
2. Do areas inside and outside the conservation zone differ in habitat diversity and composition?
3. Did changes in agricultural land use practices within the last 20 years affect the biodiversity of meadows in the Biosphere Reserve Wienerwald, and what are the implications for management and conservation of grasslands?

Material and Methods

Research question 1 – differences of meadows inside and outside the conservation zone

Field sampling

During the MaB-project “Diversity of meadows and dry grasslands in the biosphere reserve Wienerwald – a pilot study”, 886 vegetation samples (relevés) from the literature and 245 relevés newly sampled in 2010 were gathered in a TURBOVEG database (see Willner et al. 2013 for details). However, a first screening of the data showed that we needed some additional relevés with precise coordinates from outside the conservation zone. Using an unpublished GIS-layer of meadows in the biosphere reserve Wienerwald which included a coarse classification into the types (i) mesic meadows, (ii) wet meadows and (iii) dry and semi-dry grasslands (AVL, ined.), we randomly selected 55 sites from those which are not included in the conservation zone. Sampling took place in May and June 2011. Plot size was 5×5 m.

In addition to the 55 randomly selected sites, we used a data set of 201 relevés sampled by Thomas Wrbka in the course of the biotope mapping of the biosphere reserve, mainly from the area of Klosterneuburg. These relevés included locations inside and outside the conservation zone.

Data analysis

To avoid biased results due to temporal changes within the studied meadows, we used only plots that were sampled between 2001 and 2012. Plots with $\geq$ 15% cover of the tree or shrub layer were excluded. Thus, our final data set comprised 749 relevés, of which 534 were located inside and 215 outside the conservation zone (Fig. 1). A detailed overview of the data sources is given in Table 1.

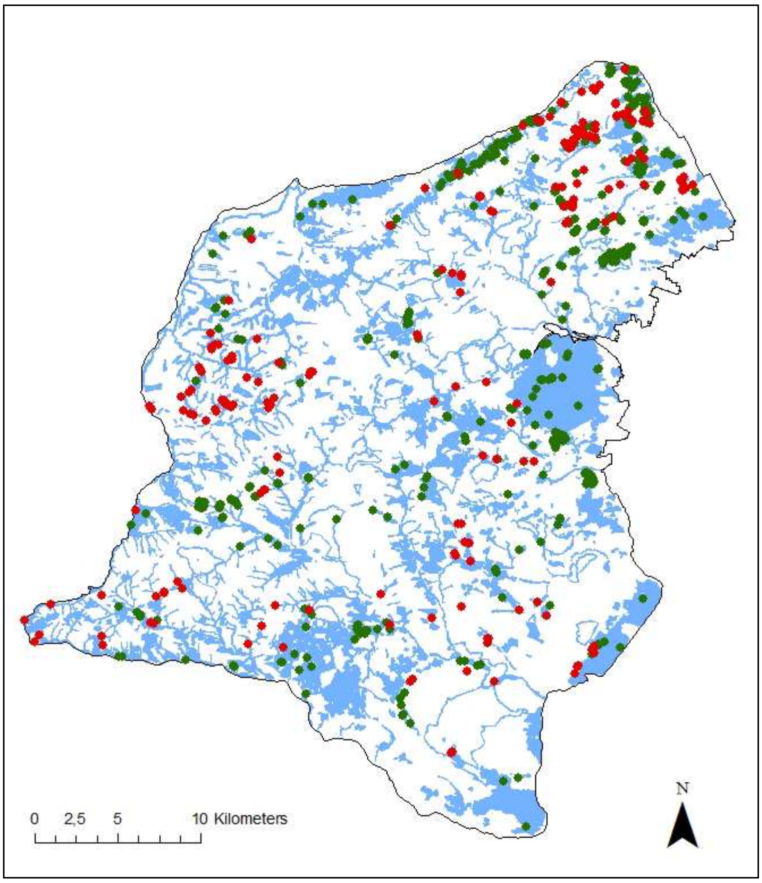

Fig. 1: Location of the compared plots from inside (green) and outside (red) the conservation zone (blue area).

Table 1: Data sources for the comparison of meadows inside and outside the conservation zone.

source	sample years	number of plots
A. Lichtenecker (ined.), Vegetationskartierung Eichwiese	2001	42
W. Willner, relevés from Willner et al. (2004)	2001	5
M. Schardinger (2005), Diploma thesis	2003	36
N. Sauberer, unpublished relevés from the Thermenlinie	2005-2011	36
W. Willner, unpublished relevés from the Thermenlinie	2009	2
W. Willner et al., MaB project WiBiWi	2010	243
M. Staudinger, Offenlandkartierung and Biotopkartierung Wien	2010-2011	40
K. Hülber, D. Moser, N. Sauberer, W. Willner; randomly selected sites	2011	55
V. Grass, resampling of the plots of Huspeka 1993	2011	85
W. Willner, resampling of the plots of Ebenberger 1993	2011	7
T. Wrbka, Offenlandkartierung Klosterneuburg	2011	198

We compared species numbers and numbers of red list species (according to Niklfeld & Schratt-Ehrendorfer 1999) of the plots from inside (N = 534) and outside (N = 215) the conservation zone. Significance was tested with Student's t test. In addition to the overall difference between meadows inside and outside the conservation zone, we compared these parameters also separately for individual grassland types using the phytosociological classification of Willner et al. (2013).

Research question 2 – differences in habitat diversity inside and outside the conservation zone

Dataset

For comparing habitat diversity and composition inside and outside the conservation zone, we used data of the biotope mapping of the biosphere reserve. These data included the revised digital map of the area “Thermenlinie” (see below) as well as data of some other areas that have been mapped in 2011 and 2012.

Within the project “Vineyard landscapes” (EU program for the development of rural areas – Ländliche Entwicklung), a digital habitat map of the area “Thermenlinie”, the easternmost part of the Biosphere Reserve Wienerwald, was elaborated. The polygons were digitised using a WebGIS application provided by the Austrian Federal Forests (ÖBF). As this application is no longer maintained, extraction of the data and their transformation into a format that can be processed with ArcGIS was not an easy task. Moreover, some of the original habitat types were too broadly defined (e.g. “meadows”, “dry grassland”). Therefore, several areas were re-visited in spring 2012 and the habitat map was refined according to the biotope list used for the complete biotope mapping of the biosphere reserve which started in 2011.

The biotope types used for the mapping of the biosphere reserve are listed in Appendix 1. An example from the revised habitat map of the “Thermenlinie” is shown in Fig. 2.

Data analysis

In a first step, we randomly distributed 1000 points within the mapped area. Then we buffered the points to circles with 200 m radius. The smallest distance allowed between two random points was set to 200 m to prevent strong overlap, which resulted in 873 circles fulfilling the distance criterion (Fig. 3). Next we excluded all circles at the border of the study area as well as all circles including less than 75% of mapped area (i.e., circles with more than 25% forests or settlement area). A circle was classified as "inside" when more than 70% of its area belonged to the conservation zone and it was classified as "outside" when less than 30% of its area belonged to the conservation zone. Circles with a percentage of 30–70% within the conservation zone were not used. This resulted in a set of 159 test circles inside and 179 circles outside the conservation zone (Fig. 4). “Inside” and “outside” circles had no difference in the area of forests and settlements (means of mapped area within the circle: 93% and 92%, respectively; $p = 0.468$).

For each circle, we calculated the number of biotope types, the Shannon-Wiener Diversity Index of biotopes, the number of Natura 2000 habitat types and the percentage of area covered by Natura 2000 habitats. Differences between circles inside and outside the conservation zone were tested using Student's t test.

Moreover, we calculated the total mapped area of selected habitat types inside and outside the conservation zone and the portion of the total area of the habitat that is located within the conservation zone. All spatial analyses were done using ArcGIS.

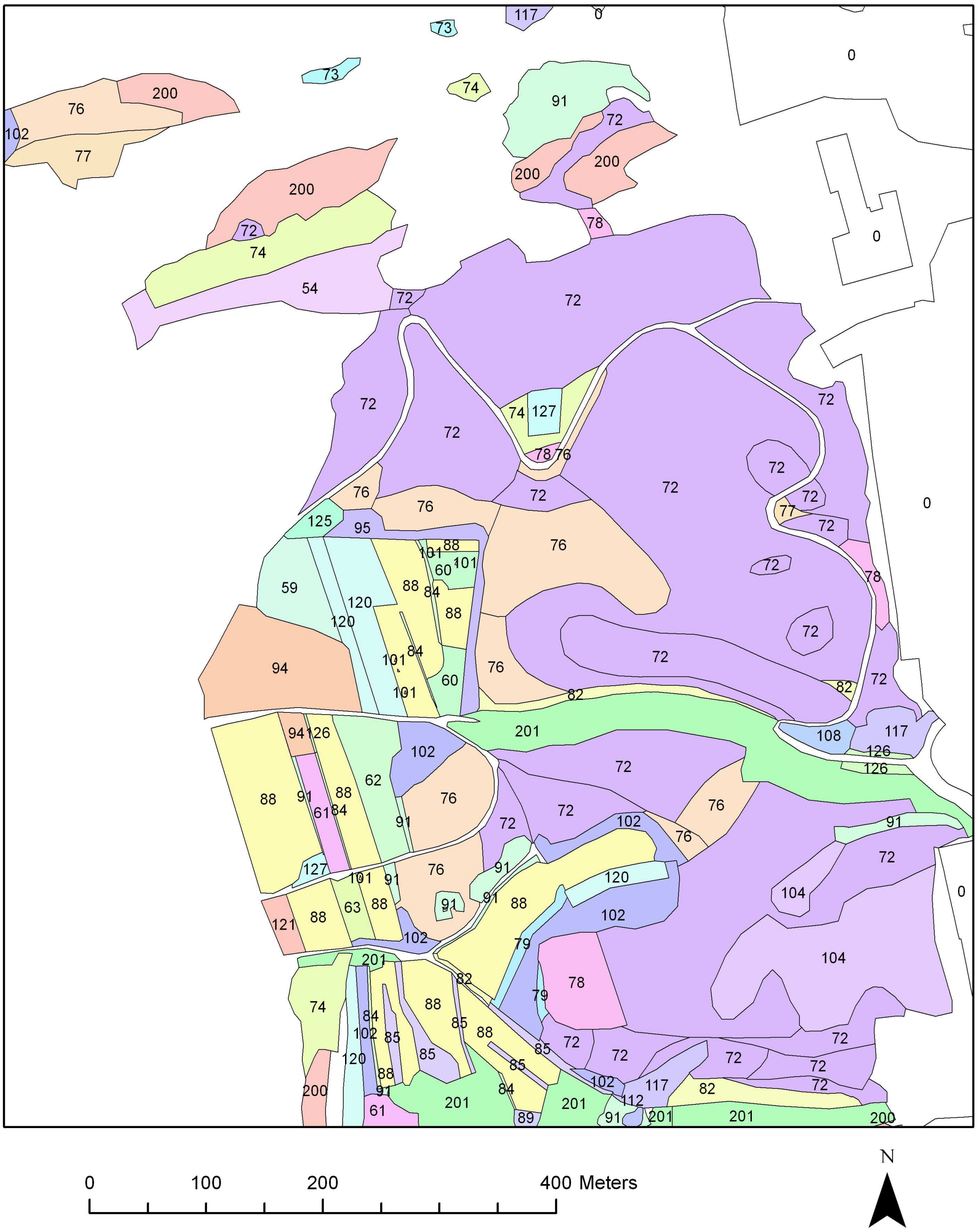

Fig. 2: Extract from the revised biotope map of the “Thermenlinie” (area of Perchtoldsdorf). The numbers refer to the mapping units given in Appendix 1.

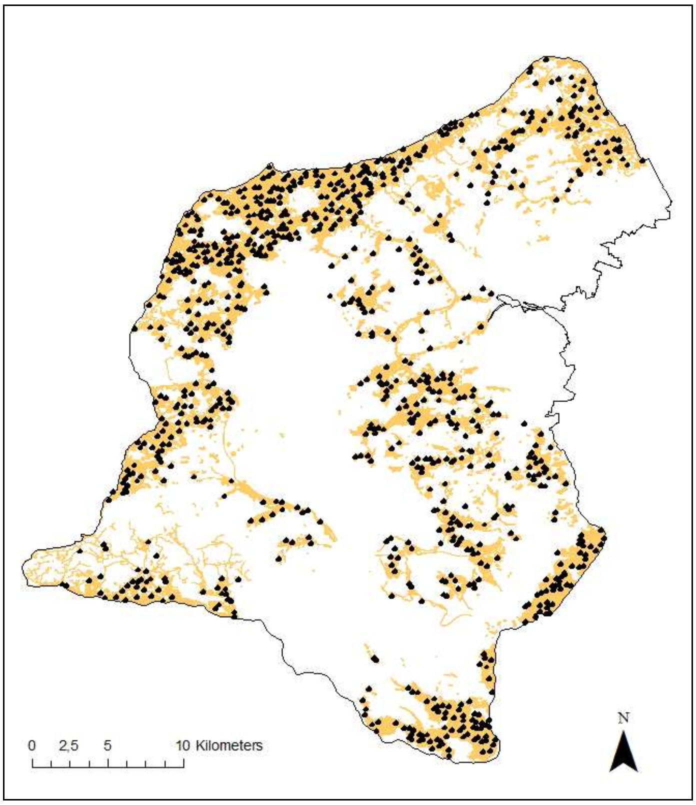

Fig. 3: 873 test circles with 200 m radius, randomly distributed within the currently mapped area of the biosphere reserve (orange area).

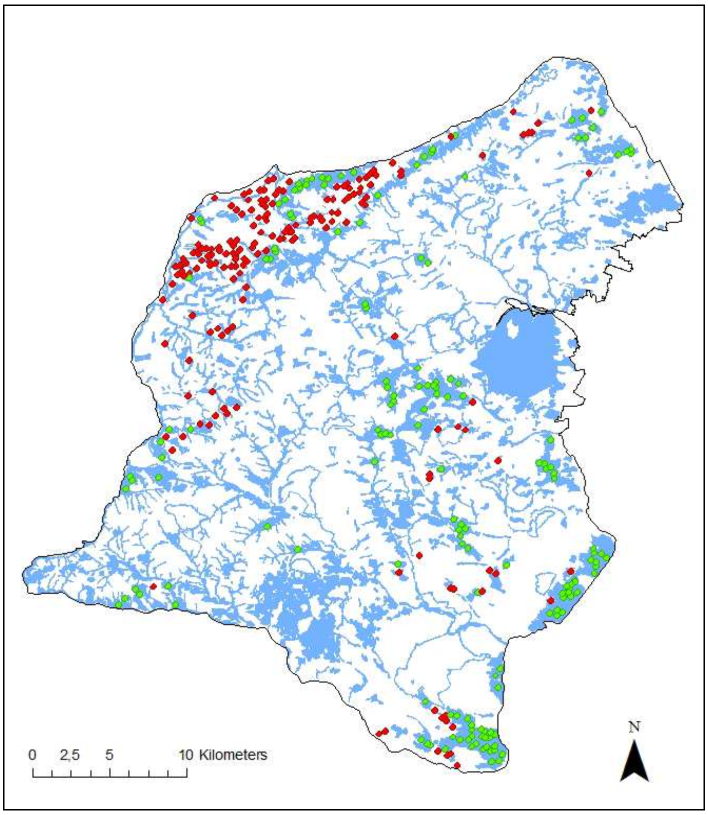

Fig. 4: Test circles located with > 70% of their area inside (green; N = 159) and outside (red; N = 179) the conservation zone (blue area).

Research question 3 – changes within the last 20 years

To evaluate changes in the biodiversity of meadows within the last 20 years, we selected two test areas for which a sufficient number of relevés older than 15 years was available and for which the sampling site could be located with ± 5 m precision. These test areas were (a) the meadows along the northern edge of the Vienna Woods (data from Huspeka 1993, sampled in 1990), and (b) the meadows in the surrounding of Sophienalpe and Mostalm in the 14th district of Vienna (data from Ebenberger 1993, sampled in 1992). Altogether, 105 sites were re-sampled in 2011 (Fig. 5).

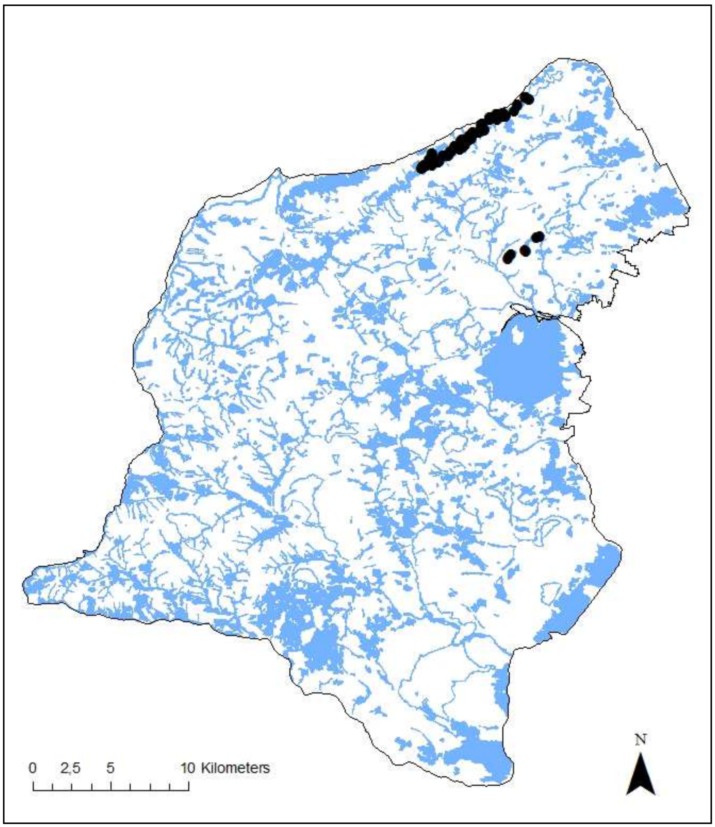

Fig. 5: Location of the 105 re-sampled plots. Blue area: conservation zone.

Field sampling

The sampling took place in May and June 2011. Relevé size was always 5×5 m. As in the studies of 1990/92 only the approximate range of plot sizes was given (ca. 15–25 m²), we used the upper limit of the original range to ensure that an observed decrease in the species number was not attributable to smaller plot sizes.

Data analysis

We compared the historic and recent relevés in respect of species richness (number of vascular plant species), total cover, number of endangered species according to the Austrian red list (Niklfeld & Schratt-Ehrendorfer 1999) and their proportion on the total species richness as well as number and proportion of graminoid species (*Poaceae* and *Cyperaceae*). Significance was tested using paired t-tests.

Moreover, we classified the sites according to the duration of management within the framework of the Austrian Agri-environmental Programme (ÖPUL): 45 sites have never been included in ÖPUL, of which 15 sites have been abandoned (further referred to as group AB) and 30 sites have been conventionally managed (group CO); 31 sites have been included for one period (i.e., for five years; group OP1), and 29 sites have been included for at least two periods (i.e., for at least ten years; group OP2). We tested for significant associations between the change in biodiversity indices and these groups using ANOVA and Tukey post-hoc test.

To characterise environmental conditions on sites, mean Ellenberg indicator values (Ellenberg et al. 1992) weighted by species abundance were calculated for each relevé. Abundance classes of the Braun-Blanquet scale were transformed using the mean of the respective range of abundances for each class, i.e., r = 0.2%, + = 1%, 1 = 3%, 2m = 5%, 2a = 10%, 2 = 15%, 2b = 20%, 3 = 37%, 4 = 62%, 5 = 87%. We used Ellenberg indicator values describing ecological requirements of plant species in terms of nutrients (N), light (L) and soil moisture (M). These indicator values range from one (low requirements) to nine (high requirements). For species indifferent to particular indicator values we used the median of the concerned indicator values at the site.

We applied a Principal Component Analysis (PCA) based on the weighted mean Ellenberg indicator values of relevés. Group AB was excluded to avoid distorting effects of abandonment. Differences in PCA-axes values between historic and recent relevés, calculated separately for each site, were used in a Multivariate Analysis of Variance (MANOVA) without predictor variables (i.e., using only the intercept). This approach was performed for the overall dataset (groups CO, OP1 and OP2) as well as for each group separately. Shifts along the axes being significantly different from zero were interpreted as a change in site conditions.

Differences in the changes of individual mean Ellenberg indicator values among groups were tested using ANOVA and Tukey post-hoc test.

Results

Research question 1 – differences of meadows inside and outside the conservation zone

Grassland plots inside the conservation zone had a significantly higher species richness than plots outside, both with respect to the overall number of vascular plant species and the number of red list species (Fig. 6). However, grasslands not located within the conservation zone still hosted an average of 2.02 threatened species per plot (compared to 2.66 species per plot inside the conservation zone).

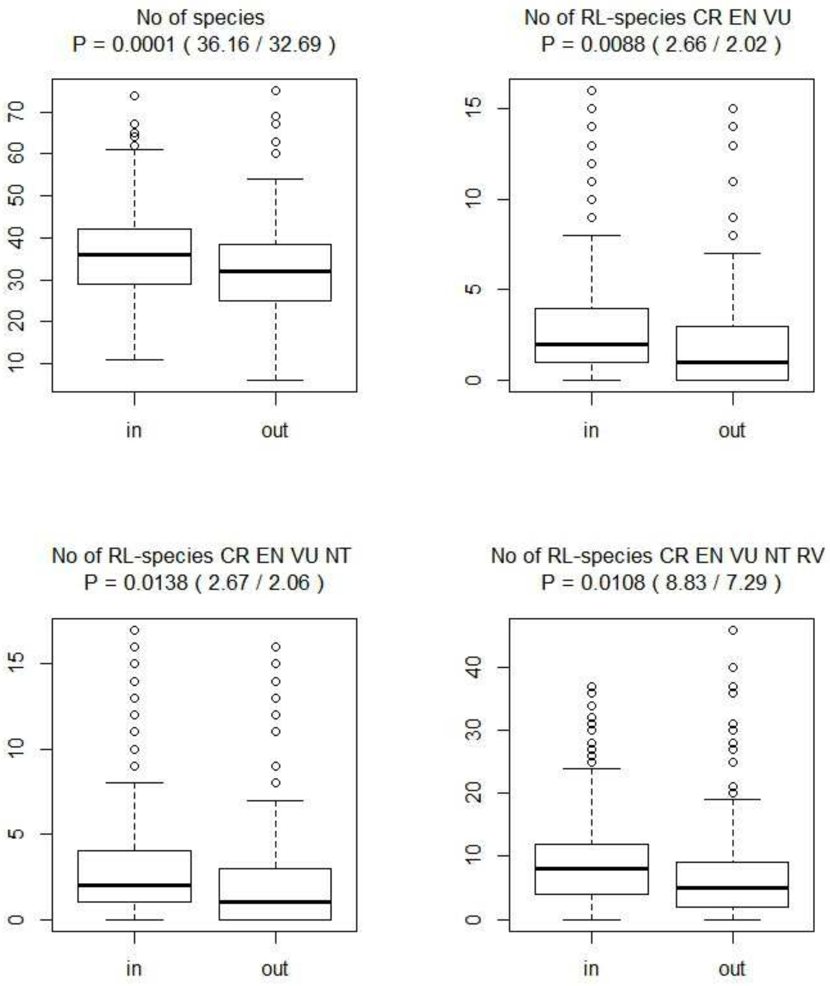

Fig. 6: Comparison of species diversity of plots inside and outside the conservation zone. Upper left: total number of vascular plant species, upper right: number of threatened species (red list categories CR = critically endangered, EN = endangered, VU = vulnerable), lower left: number of threatened and near-threatened (NT) species, lower right: number of threatened, near-threatened, and regionally threatened (RV) species. P-values are estimates from Student's t test. Numbers in brackets are means, the band inside the box are medians.

When plots of individual grassland types are compared, the differences in species richness and number of red list species is mostly not significant, although a trend for higher richness within the conservation zone is visible in most cases (Fig. 7 and 8). Contrary to this general trend, rocky grasslands (*Fumano-Stipetum* and *Scorzonero-Caricetum humilis*) and calcareous semi-dry grasslands (*Polygalo-Brachypodietum*) showed higher mean species richness and number of red list species outside the conservation zone.

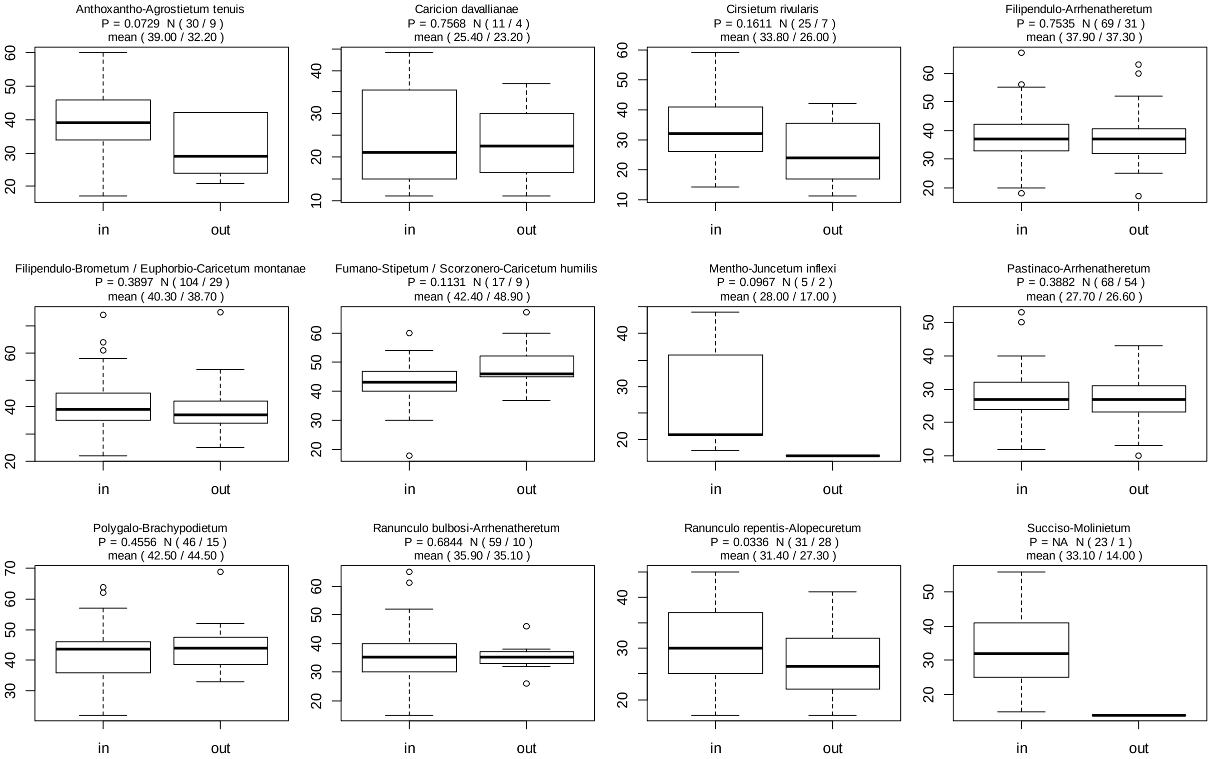

Fig. 7: Comparison of species numbers of vascular plants of different grassland types inside and outside the conservation zone. N: number of observations (inside / outside); mean: average species number per plot (inside / outside). P-values are estimates from Student's t test, the band inside the box are medians. For *Succiso-Molinietum*, no significance could be calculated because there was only one observation outside the conservation zone.

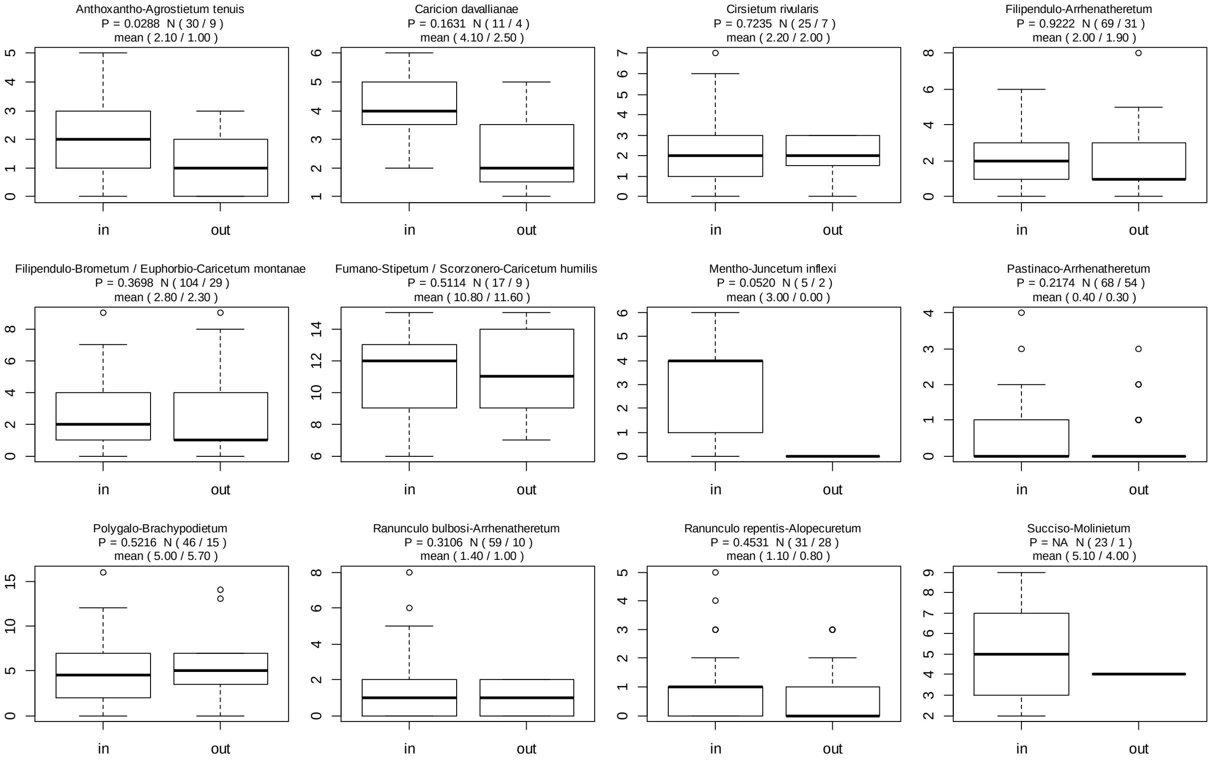

Fig. 8: Comparison of species numbers of red list vascular plants (categories CR, EN and VU) of different grassland types inside and outside the conservation zone. N: number of observations (inside / outside); mean: average species number per plot (inside / outside). P-values are estimates from Student's t test, the band inside the box are medians. For *Succiso-Molinietum*, no significance could be calculated because there was only one observation outside the conservation zone.

Research question 2 – differences in habitat diversity inside and outside the conservation zone

All indices of habitat diversity (i.e., number of habitat types, Shannon diversity index, number and area of Natura 2000 habitat types) were significantly higher inside the conservation zone (Fig. 9). Nevertheless, a GIS analysis of the layers produced by the biotope mapping revealed that for several grassland types of high conservation interest more than 25% of their total habitat area was found outside the conservation zone (Table 2). The best coverage was found for semi-dry grasslands, while relatively nutrient-poor *Arrhenatherum* meadows (*Ranunculo bulbosi*- and *Filipendulo-Arrhenatheretum*) are less well represented. Dry grasslands of the alliance *Seslerio-Festucion pallentis* (*Fumano-Stipetum* and *Scorzonero-Caricetum humilis*) as well as intermittently wet *Molinia* meadows (*Succiso-Molinietum*) are among the grassland types with the worst coverage by the conservation zone.

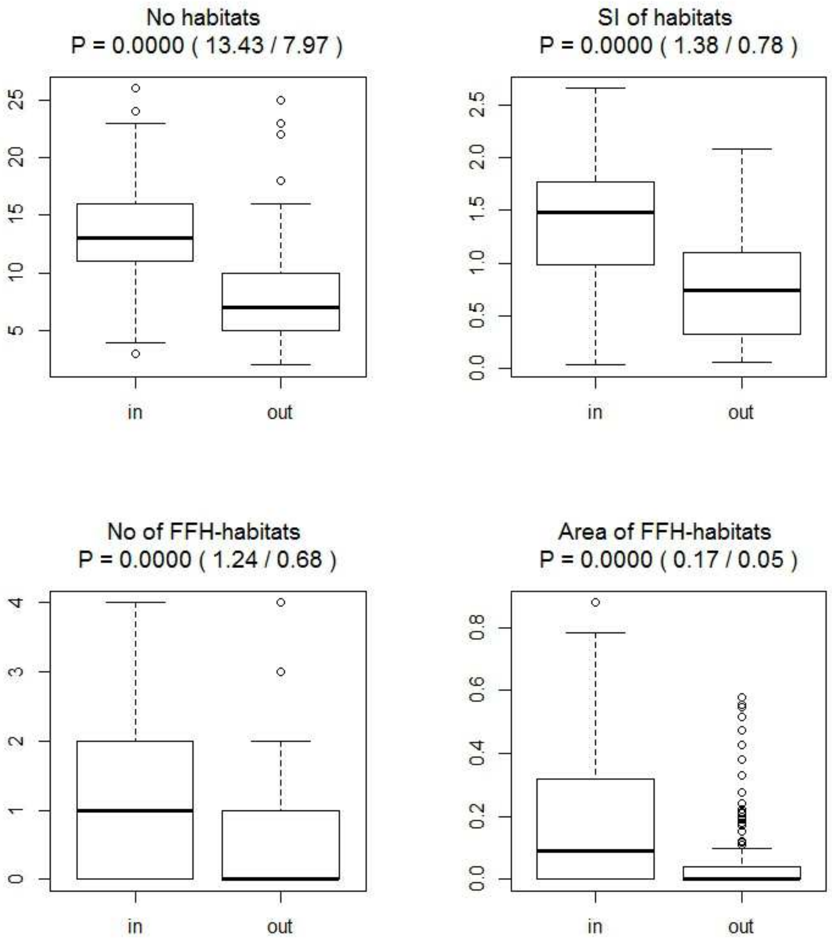

Fig. 9: Comparison of habitat diversity within test circles of 200 m radius inside and outside the conservation zone. Upper left: total number of habitat types, upper right: Shannon Index of habitat diversity, lower left: number of Natura 2000 habitat types, lower right: area of Natura 2000 habitat types. P-values are estimates from Student's t test. Numbers in brackets are means, the band inside the box are medians.

Table 2: Total mapped area of grassland types of conservation interest inside and outside the conservation zone and percentage of habitat area covered by the conservation zone. ID: Biotope Code (see Appendix 1), Natura 2000: corresponding Natura 2000 habitat type. The biotope types are ordered by decreasing coverage.

ID	Biotope name and corresponding plant community	Natura 2000	inside (ha)	outside (ha)	% inside
76	beweidete Halbtrockenrasen (Cirsio-Brachypodion p.p.)	6210	77.6	7.0	92
75	wechseltrockene Trespenwiesen (Euphorbio-Caricetum, Filipendulo-Brometum)	6210	324.8	88.6	79
74	Trockene Trespenwiesen (Polygalo-Brachypodietum)	6210	96.7	26.8	78
41	gedüngte feuchte Fettwiesen (Calthion palustris)	-	18.4	5.9	76
64	Magere Rotschwingel-Wiese, incl. Mäh-Bürstlingsrasen (Anthoxantho-Agrostietum)	6230	37.2	11.8	76
57	Fuchsschwanz-Frischwiese (Ranunculo repentis-Alopecuretum)	6510	76.6	29.7	72
24	Basenreiches, nährstoffarmes Kleinseggenried (Caricion davallianae)	7230	7.8	3.2	71
55	Wechselfeuchte Glatthaferwiese (Filipendulo vulgaris-Arrhenatheretum)	6510	549.7	227.8	71
72	Fels-Trockenrasen (Seslerio-Festucion pallentis)	6190	20.2	8.8	70
54	Trockene Glatthaferwiesen (Ranunculo bulbosi-Arrhenatheretum)	6510	300.1	157.6	66
37	Pfeifengras-Streuwiese (Succiso-Molinietum)	6410	20.6	11.0	65
56	Glatthafer-Fettwiese (Pastinaco-Arrhenatheretum)	-	781.3	576.4	58

Research question 3 – changes within the last 20 years

We found a general decrease of the average species richness at the scale of 25 m² from ca. 43 species in the early 1990ies to 30 species in 2011. Threatened species decreased from ca. 11 species to 7 species. We also found a slight increase of the total cover of the herb layer and of the proportion of graminoid species (Fig. 10). Sites which have been managed within the framework of the Austrian Agri-environmental Programme (ÖPUL) showed a trend to lesser decrease of species compared to conventionally managed sites but this difference was not significant. However, ÖPUL sites had a significantly lower decrease of species than abandoned sites for both total species numbers and threatened species (Fig. 11, Table 3).

Mean Ellenberg indicator values of all sites differed significantly between the historic and the recent observation (Pillai = 0.23; $F_{3,87} = 8.65$; $p < 0.001$). This shift was mainly along the direction of increasing Ellenberg indicator values for nutrients and moisture (Fig. 12). Differences between the two survey periods were strongest for sites of group CO (Pillai = 0.46; $F_{3,27} = 7.79$; $p < 0.001$) (note that group AB was excluded from the PCA), less strong for sites of group OP1 (Pillai = 0.29; $F_{3,28} = 3.82$; $p < 0.020$) and non-significant for sites of group OP2 (Pillai = 0.24; $F_{3,26} = 2.72$; $p < 0.065$).

Differences between management groups were significant with regard to light values, but not for moisture and nutrient values (Fig. 13, Table 4). Thus, the overall increase in Ellenberg indicator values for nutrients and moisture was almost the same among all four groups.

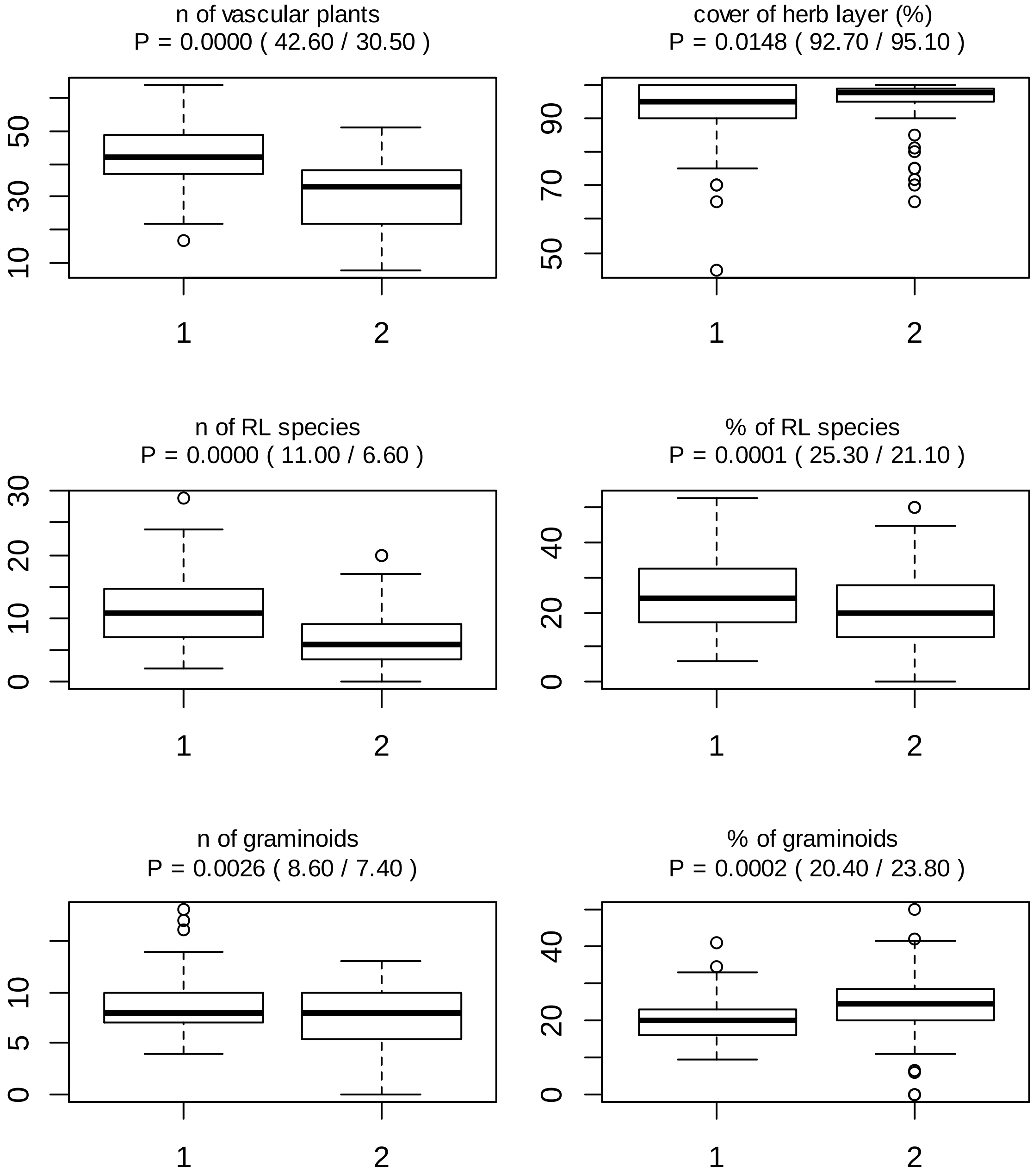

Fig. 10: Overall change of species number per plot, cover of the herb layer, number and proportion of red list species (RL) and number and proportion of graminoid species between 1990/92 (1) and 2011 (2).

Changes in the frequency and average cover of individual species are given in Appendix 2.

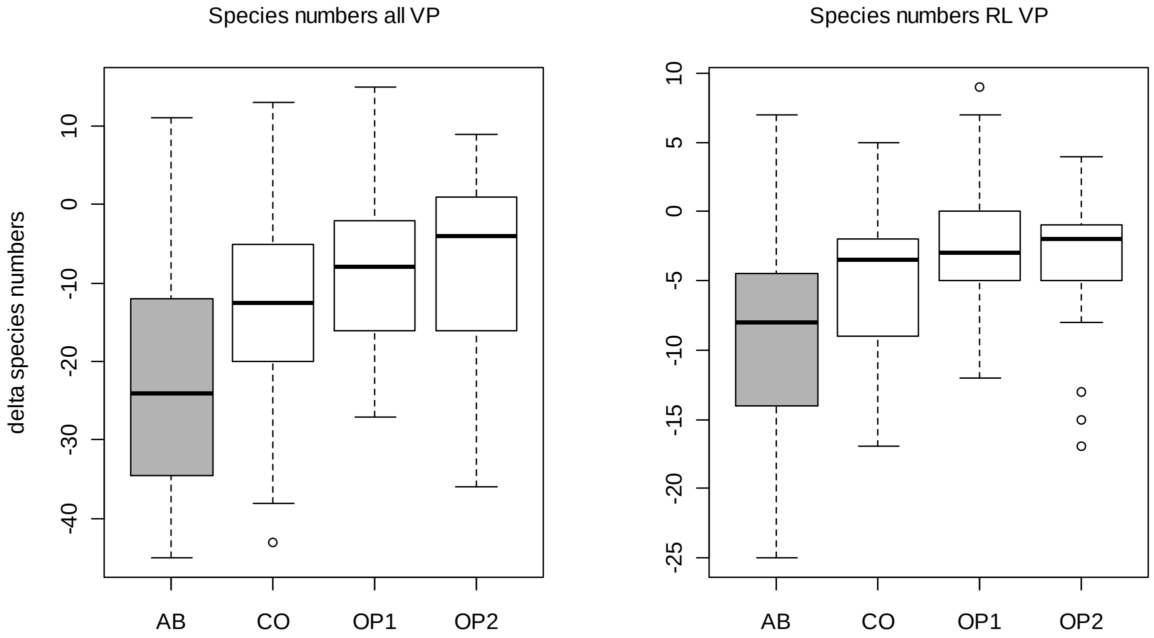

Fig. 11: Changes in species numbers of all vascular plants (left) and red list vascular plants (right) within the period 1990/92 to 2011. AB (N=15): abandoned grasslands, CO (N=30): conventional management, OP1 (N=31): one ÖPUL-period; OP2 (N=29): two ÖPUL-periods.

Table 3: ANOVA and post-hoc test for changes in (a) species numbers and (b) numbers of red list species. Significance codes: ***: p < 0.001, **: p < 0.01, *: p < 0.05.

(a) Species numbers

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
	3	2581.8	860.59	5.4444	0.001643 **
Residuals	101	15965.0	158.07		

Tukey multiple comparisons of means

	diff	lwr	upr	p adj
OP1-CO	5.2709677	-3.140540	13.682475	0.3627349
OP2-CO	5.4344828	-3.118484	13.987449	0.3503208
AB-CO	-8.9333333	-19.319383	1.452716	0.1177673
OP2-OP1	0.1635150	-8.321374	8.648404	0.9999539
AB-OP1	-14.2043011	-24.534361	-3.874242	0.0028212 **
AB-OP2	-14.3678161	-24.813385	-3.922247	0.0028102 **

(b) Numbers of red list species

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
	3	367.59	122.531	3.9884	0.009916 **
Residuals	101	3102.92	30.722		

Tukey multiple comparisons of means

	diff	lwr	upr	p adj
OP1-CO	1.9946237	-1.713677	5.7029246	0.4991262
OP2-CO	1.4540230	-2.316642	5.2246876	0.7454893
AB-CO	-3.7000000	-8.278798	0.8787984	0.1566158
OP2-OP1	-0.5406007	-4.281253	3.2000513	0.9815655
AB-OP1	-5.6946237	-10.248738	-1.1405089	0.0079858 **
AB-OP2	-5.1540230	-9.759061	-0.5489848	0.0218493 *

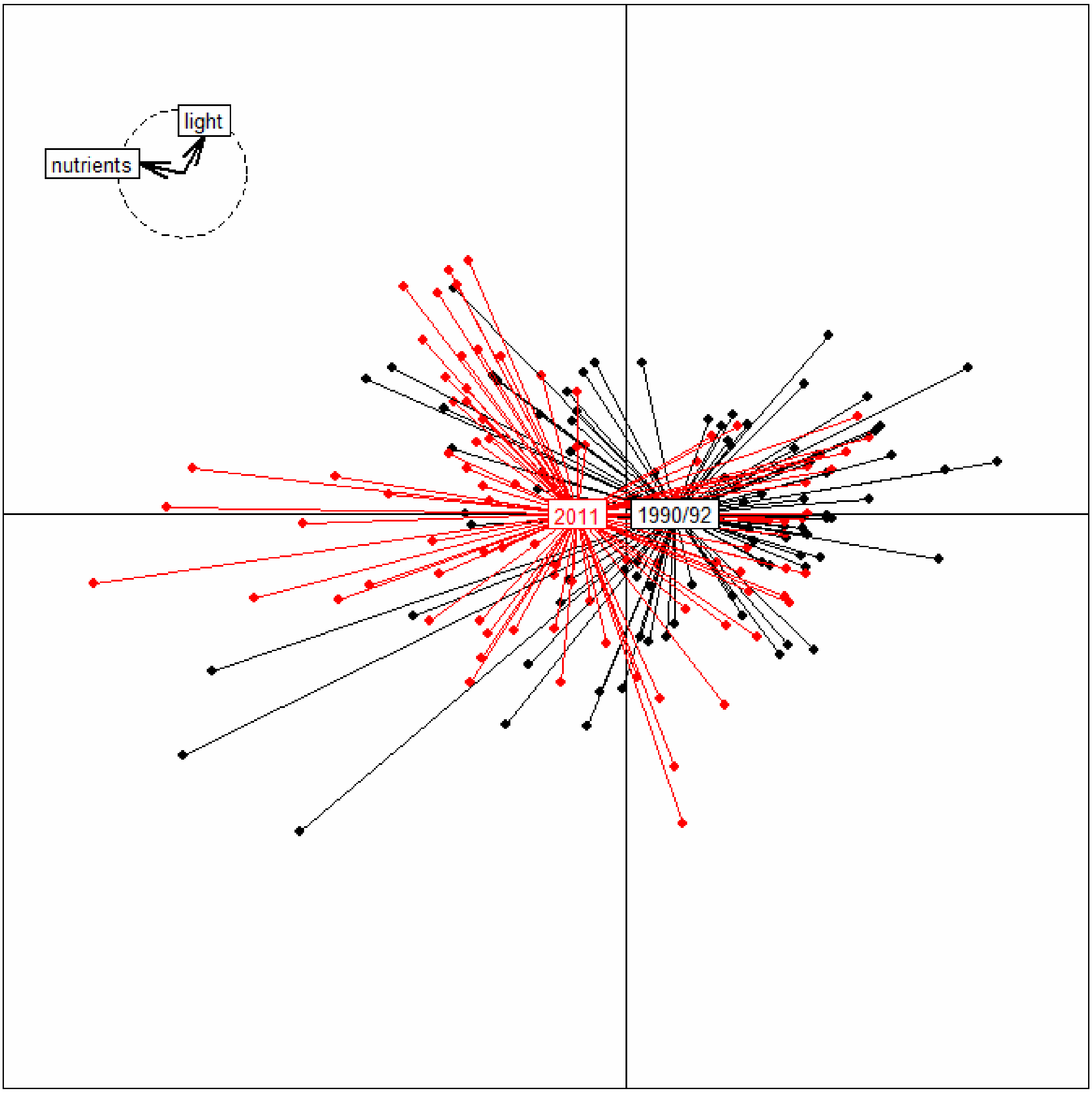

Fig. 12: PCA (first and second axis) based on mean Ellenberg indicator values calculated for historic (1990/1992) and recent (2011) relevés of 90 meadow sites in the Biosphere Reserve Wienerwald. Lines connect each relevé with the centroid (i.e. gravity point) of the respective survey. The insert indicates the loadings of indicator values on the ordination axes. The indicator values for moisture and nutrients are highly correlated (Pearson´s r = 0.99) and, therefore, the arrow for moisture cannot be seen. Abandoned sites were excluded from this analysis.

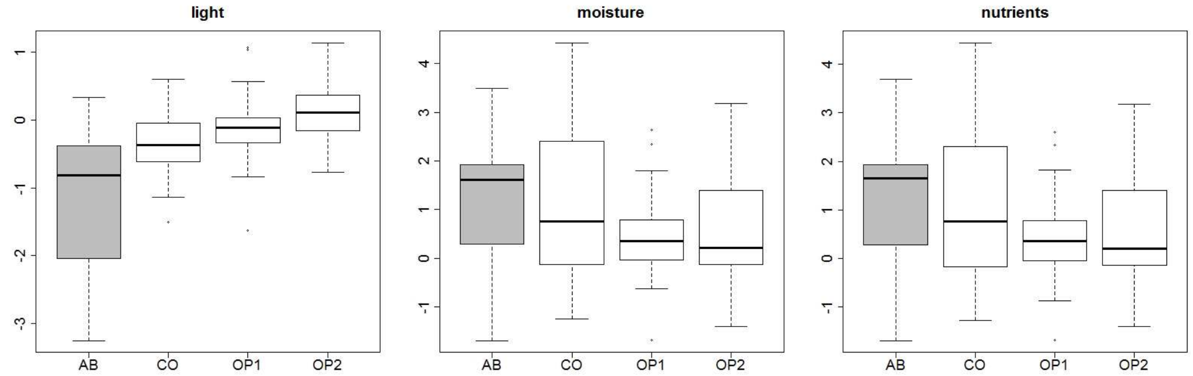

Fig. 13: Changes in mean Ellenberg indicator values for light, moisture and nutrients within the period 1990/92 to 2011. AB (N=15): abandoned grasslands, CO (N=30): conventional management, OP1 (N=31): one ÖPUL-period; OP2 (N=29): two ÖPUL-periods.

Table 4: ANOVA and post-hoc test for changes in mean Ellenberg indicator values. Significance codes: ***: p < 0.001, **: p < 0.01, *: p < 0.05.

(a) light values

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
	3	19.51	6.502	17.61	2.84e-09 ***
Residuals	101	37.28	0.369		

Tukey multiple comparisons of means

	diff	lwr	upr	p adj
OP1-CO	0.2267360	-0.17975141	0.6332234	0.4671557
OP2-CO	0.5079912	0.09466779	0.9213147	0.0094709 **
AB-CO	-0.8629514	-1.36485884	-0.3610439	0.0001098 ***
OP2-OP1	0.2812552	-0.12877837	0.6912888	0.2832369
AB-OP1	-1.0896874	-1.58888914	-0.5904856	0.0000007 ***
AB-OP2	-1.3709426	-1.87572637	-0.8661588	0.0000000 ***

(b) moisture values

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
	3	8.25	2.749	1.657	0.181
Residuals	101	167.58	1.659		

(c) nutrients values

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
	3	8.85	2.950	1.731	0.165
Residuals	101	172.12	1.704		

Discussion

Delimitation of the conservation zone

It became clear from our analysis that there exist valuable grasslands also outside the conservation zone. Indeed, the difference in species richness and number of red list species among grasslands inside and outside the conservation zone is not very high, though statistically significant (Fig. 6). There were up to 15 threatened species found in plots outside the conservation zone. When we restricted the comparison to individual grassland types, the differences became mostly non-significant (which is partly an effect of the lower number of observations). Three associations showed even higher species richness outside than inside the conservation zone (Fig. 7, 8). This striking result can be explained by the fact that several species rich grasslands along the Thermenlinie are presently not included in the conservation zone (Fig. 14).

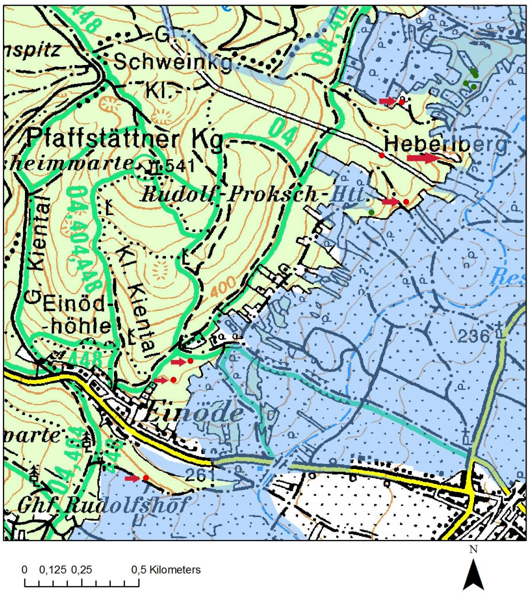

Fig. 14: Delimitation of the conservation zone (blue area) between Pfaffstätten and Gumpoldskirchen. The red arrows point to species rich grasslands (rocky steppes and semi-dry grasslands) which are presently not included in the conservation zone.

In respect to habitat diversity, the conservation zone clearly covers the most diverse areas within the biosphere reserve (Fig. 9). For several grassland types of high conservation priority, however, only 3/4 of their total area within the biosphere reserve is presently included in the conservation zone (Table 2).

The biotope mapping, which will be completed in 2013, will provide a solid basis for the amendment of the conservation zone. There is general agreement that the conservation zone should not cover all non-forest areas within the biosphere reserve because this would devaluate the zonation as an instrument for land use planning and nature conservation. However, a considerable number of valuable grassland patches seem to have slipped through the first delimitation process and should be added to the conservation zone in the future.

Changes in the biodiversity of meadows since the 1990ies

The meadows of the Vienna Woods are much less intensively used than grasslands in other regions of Austria (Willner et al. 2013). One explanation for this is that cattle farming is not very common in the Vienna Woods, and grasslands are mainly used as hay meadows to fed horses. Nevertheless, species rich grasslands have also declined in our study region during the last decades, mainly due to abandonment and subsequent succession. The observed decline in overall species richness and especially in the number of rare, endangered species (Fig. 10) is a clear indicator of this general trend of abandonment on the one hand and intensification on the other hand.

Species richness and number of red list species decreased in all four groups, even in sites included in the Austrian Agri-environmental Programme (ÖPUL) for at least ten years. Significant differences were only detected between ÖPUL sites and abandoned grasslands. However, there is a tendency towards lower decrease in sites managed within the framework of ÖPUL (Fig. 11). The increase in mean Ellenberg indicator values for nutrients and moisture (Fig. 12) can be interpreted as an overall increase of nutrient-demanding, competitive species with an optimum in mesic, fertilised grasslands and a decrease of species indicating nutrient-poor conditions. Again, this general trend was not significantly different in sites included and not included in ÖPUL but a tendency towards better conditions under ÖPUL management could be detected (Fig. 13). A strong decrease in mean Ellenberg indicator values for light was observed in abandonded sites. This finding can mainly be explained by the strong increase of *Brachypodium pinnatum,* a species indicating grassland abandonment (Bobbink & Willems 1993).

Wrbka et al. (2008) found a positive effect of the ÖPUL measures in Austrian grasslands, observing a significant increase in the vascular plant species richness within 25 m² plots between 1998 and 2003. However, they also reported that this effect was mostly attributable to rather common species while the number of Red List species had not increased. In our study area, the effect of ÖPUL is a deceleration of biodiversity loss rather than a reversal of this general trend. Obviously, the current agri-environmental schemes are not sufficient to preserve the most diverse grasslands and the highly endangered species (Kleijn et al. 2006, Wilson et al. 2007). Their most important effect is probably to maintain the management of meadows which otherwise would have been abandoned.

There are several initiatives and projects which stem against this loss of biodiversity in agricultural landscapes. Since 2006, farmers are awarded for the best management of species-rich grasslands in a yearly, regional championship (*Wiesenmeisterschaft*). This competition raises the awareness for grasslands as habitats and old cultural heritage. Between 2004 and 2008, the LIFE-Nature project “Pannonic Steppes and Dry Grasslands” successfully enlarged areas of dry grasslands through the means of acquisition of land, clearing of trees and shrubs, and initiating extensive pasturing with sheeps in some areas. In 2010, a project was launched within the Rural Development Policy of the European Union to improve the situation of dry and semi-dry grasslands in three municipalities at the easternmost border of the Vienna Woods.

With regard to agri-environment schemes, switching to a “payment by result” might be a promising approach. In this way, farmers would be payed for the outcome of their activities and thus be encouraged to engage with conservation issues rather than performing predetermined management activities (de Snoo et al. 2013).

Cited Literature

Becker B., Kainz S., Kraus R., Pollheimer M., Reiter K., Schoberleithner W., Scholl S., Schopper G., Wrbka E. & Wrbka T. (2004): Detailplanung Biosphärenpark Wienerwald, Bereich Offenland. – Unveröff. Studie im Auftrag des Biosphärenparks Wienerwald.

Bobbink R. & Willems J. H. (1993): Restoration management of abandoned chalk grassland in the Netherlands. – Biodiversity and Conservation 2: 616–626.

Caro T. M. (2001): Species richness and abundance of small mammals inside and outside an African national park. – Biological Conservation 98: 251–257.

Ebenberger H. (1993): Die Vegetation von Sophienalpe und Mostalm im Wienerwald. – Diplomarbeit, Univ. f. Bodenkultur Wien.

Ellenberg H., Weber H.E., Düll R., Wirth V., Werber W. & Paulißen D. (1992): Zeigerwerte von Pflanzen in Mitteleuropa. 3. Aufl. – Scripta Geobotanica 18. Verlag Erich Goltze, Göttingen.

Essl F., Willner W., Egger G., Ellmauer T., Steiner G. M. & Moser D. (2008): Diversitätsmuster der Wälder, Moore, Feucht- und Trockenwiesen in Österreich – ein erster Überblick. – In: Sauberer N., Moser D. & Grabherr G. (eds.), Biodiversität in Österreich. Räumliche Muster und Indikatoren der Arten- und Lebensraumvielfalt. – Bristol-Schriftenreihe 20: 122–143. Haupt, Zürich.

Figueroa F. & Sanchez-Cordero V. (2008): Effectiveness of natural protected areas to prevent land use and land cover change in Mexico. – Biodiversity and Conservation 17: 3223–3240.

Huspeka J. (1993): Wiesen und Wiesenbrachen an der Nordabdachung des Wienerwaldes. – Diplomarbeit, Univ. Wien.

Kleijn D., Baquero R.A., Clough Y. et al. (2006) Mixed biodiversity benefits of agri-environment schemes in five European countries. – Ecology Letters 9: 243–254.

Kuussaari M., Bommarco R., Heikkinen R. K., Helm A., Krauss J., Lindborg R., Ockinger E., Pärtel M., Pino J., Rodà F., Stefanescu C., Teder T., Zobel M. & Steffan-Dewenter I. (2009): Extinction debt: a challenge for biodiversity conservation. – Trends in Ecology and Evolution 24: 564–571.

Niklfeld H. & Schratt-Ehrendorfer L. (1999): Rote Liste gefährdeter Farn- und Blütenpflanzen (Pteridophyta und Spermatophyta) Österreichs. 2. Fassung. – In: Niklfeld H. (ed.), Rote Listen gefährdeter Pflanzen Österreichs. – Grüne Reihe des Bundesministeriums für Umwelt, Jugend und Familie 10: 33–130. Wien.

Niklfeld H., Schratt-Ehrendorfer L. & Englisch T. (2008): Muster der Artenvielfalt der Farn- und Blütenpflanzen in Österreich. – In: Sauberer N., Moser D. & Grabherr G. (eds.), Biodiversität in Österreich. Räumliche Muster und Indikatoren der Arten- und Lebensraumvielfalt. – Bristol-Schriftenreihe 20: 87–102. Haupt, Zürich.

Pfundner G. & Sauberer N. (2009): Wiesen im Wienerwald auf Flächen der Österreichischen Bundesforste AG: Naturschutzfachliche Erhebungen und Managementvorschläge. – Naturschutzbund NÖ im Auftrag der Österreichischen Bundesforste AG im Rahmen eines gemeinsamen Projektes mit den Biosphärenpark Wienerwald Management GmbH und finanzieller Unterstützung des Landes Niederösterreich. ÖBF, Purkersdorf.

Schön R. (2003): Die Wiesen und Weiden Niederösterreichs als Lebensraum für Tiere. – In: Wiesen und Weiden Niederösterreichs, pp. 15–40. –Amt der NÖ Landesregierung, Abteilung Naturschutz. St. Pölten.

de Snoo G. R., Herzon I., Staats H., Burton R. J. F., Schindler S., van Dijk J., Lokhorst A. M., Bullock J. M., Lobley M., Wrbka T., Schwarz G. & Musters C. J. M. (2013): Toward effective nature conservation on farmland: making farmers matter. – Conservation Letters 6: 66–72.

Wiesbauer H. (ed.) (2008): Die Steppe lebt. Felssteppen und Trockenrasen in Niederösterreich. – Amt der NÖ Landesregierung. St. Pölten.
Willner W., Sauberer N., Staudinger M., Grass V., Kraus R., Moser D., Rötzer H. & Wrbka T. (2013): Syntaxonomic revision of the Pannonian grasslands of Austria – Part II: Vienna Woods (Wienerwald). – Tuexenia 33: 421–458.
Wilson A., Vickery J. & Pendlebury C. (2007): Agri-environment schemes as a tool for reversing declining populations of grassland waders: mixed benefits from environmentally sensitive areas in England. – Biological Conservation 136: 128–135.
Wrbka T., Schindler S., Pollheimer M., Schmitzberger I. & Peterseil J. (2008): Impact of the Austrian Agri-Environmental Scheme on diversity of landscape, plants and birds. – Community Ecology 9: 217–227.
Zechmeister H. G., Schmitzberger I., Steurer B., Peterseil J. & Wrbka T. (2003): The influence of land-use practices and economics on plant species richness in meadows. – Biological Conservation 114: 165–177.

Dissemination

Publications:

Willner W., Sauberer N., Staudinger M. & Schratt-Ehrendorfer L. (2013): Syntaxonomic revision of the Pannonian grasslands of Austria – Part I: introduction and general overview. – Tuexenia 33: 399–420.

Willner W., Sauberer N., Staudinger M., Grass V., Kraus R., Moser D., Rötzer H. & Wrbka T. (2013): Syntaxonomic revision of the Pannonian grasslands of Austria – Part II: Vienna Woods (Wienerwald). – Tuexenia 33: 421–458.

Hülber K., Moser D., Sauberer N., Maas B., Staudinger M., Grass V., Wrbka T. & Willner W. (2017): Plant species richness decreased in semi-natural grasslands in the Biosphere Reserve Wienerwald, Austria, over the past two decades, despite agri-environmental measures. – Agriculture, Ecosystems and Environment 243: 10–18.

Reports to stakeholders

This report was also delivered to the Management of the Biosphere Reserve.

Appendices

1. List of the biotope types used for mapping of the biosphere reserve.
2. Changes in the frequency and average cover of the most abundant species.

Appendix 1: Biotope types used for the mapping of the biosphere reserve and for research question 2 (after M. Staudinger, unpublished).

ID	Mapping Unit (in German)
1	**BINNENGEWÄSSER, GEWÄSSER- UND UFERVEGETATION**
2	Gestreckter Bach
3	Pendelnder Bach
4	Mäandrierender Bach
5	Grundwassergespeister Bach
6	Mühlbach / Mühlgang
7	Kanal / Künstliches Gerinne
8	Begradigter, regulierter Bach
9	Kleines Gerinne / Grabengewässer
10	Periodischer Bach
11	Oligotropher naturnaher Teich und Weiher tieferer Lagen
12	Meso- bis eutropher Weiher und meso- bis eutropher naturnaher Teich tieferer Lagen
13	Poly- bis hypertropher Teich und Weiher
14	Naturnaher Tümpel
15	Naturferner Teich und Tümpel
16	Versiegelter Teich und Tümpel
17	Künstliche Gewässer in Entnahmestelle
18	Submerse Gefäßpflanzenvegetation, Schwimmblatt- und Schwimmpflanzenvegetation in Stillgewässern
19	Submerse Vegetation in Fließgewässern
20	**FEUCHTGRÜNLAND i.w.S.**
21	Quellflur der tieferen Lagen
22	Kalktuff-Quellflur
23	Degradierter (Klein-)Sumpf / degradierte Naßgalle
24	Basenreiches, nährstoffarmes Kleinseggenried
25	Basenarmes, nährstoffarmes Kleinseggenried
26	Horstiges Großseggenried
27	Rasiges Großseggenried
28	Rohrglanzgras-Röhricht
29	Schilfröhricht an Gewässern
30	Ruderales Schilfröhricht an anthropogen bedingten Standorten
31	Rohrkolbenröhricht
32	Teichbinsenröhricht
33	Pestwurzflur
34	Mädesüßflur
35	Doldenblütlerflur
36	Flussgreiskrautflur
37	Pfeifengras-Streuwiese
38	Gehölzfreie bis gehölzarme Brachfläche des nährstoffarmen Feucht- und Nassgrünlandes
39	Gehölzreiche Brachfläche des nährstoffarmen Feucht- und Nassgrünlandes
40	Feuchte bis nasse Magerweide
41	gedüngte feuchte Fettwiesen (Kohl- und Bachkratzdistelwiesen)
42	ungedüngte feuchte Fettwiesen/Sumpfwiesen (Cirisum palustre-Scirpus sylvaticus-Caltha palustris-Wiese)
43	Feuchte bis nasse Fettweide
44	Gehölzfreie bis gehölzarme Feuchtbrachen mit dominierender Pestwurz
45	Gehölzfreie bis gehölzarme Feuchtbrachen mit dominierendem Mädesüß
46	Gehölzfreie bis gehölzarme Feuchtbrachen mit dominierenden Doldenblütern
47	Gehölzfreies bis gehölzarmes Schilfröhricht und verschilfte Brachen von Feuchtstandorten
48	Gehölzfreie bis gehölzarme Brachfläche des nährstoffreichen Feucht- und Nassgrünlandes
49	Gehölzreiche Brachfläche des nährstoffreichen Feucht- und Nassgrünlandes
50	Brennnesselflur
51	Goldrutenbrache
52	sonstige Neophytenflur

53 GRÜNLAND frischer Standorte
54 Trockene Glatthaferwiesen (Ranunculo bulbosi-Arrhenatheretum)
55 Wechselfeuchte Glatthaferwiese (Filipendulo vulgaris-Arrhenatheretum)
56 Glatthafer-Fettwiese (Pastinaco-Arrhenatheretum)
57 Fuchsschwanz-Frischwiese (Ranunculo repentis-Alopecuretum)
58 Gehölzfreie bis gehölzarme Grünlandbrache des frischen Wirtschaftsgrünlandes
59 Gehölzreiche Grünlandbrache des frischen Wirtschaftsgrünlandes
60 Intensivwiese
61 Acker/ Weingartenbrache mit halbruderalem Wiesencharakter
62 Acker- und Weingartenbrachen auf nährstoffarmen Standorten mit Trockenwiesenelementen
63 Feldfutter / Einsaatwiesen / junge Ackerbrachen/ Wildäcker
64 Magere Rotschwingel-Wiese, incl. Mäh-Bürstlingsrasen (Tieflands-Bürstlingsrasen)
65 Basenarme Magerweide
66 Basenreiche Magerweide
67 Intensivweide
68 GRÜNLAND trockener Standorte
69 Karbonat-Felstrockengebüsch
70 Subkontinentale Steppengebüsche
71 Karbonat-Pioniertrockenrasen
72 Fels-Trockenrasen
73 Steppenrasen
74 Trockene Trespenwiesen
75 Wechseltrockene Trespenwiesen
76 Beweidete Halbtrockenrasen
77 Gehölzfreie bis gehölzarme Brachfläche des Halbtrocken- und Trockengrünlandes
78 Gehölzreiche Brachfläche des Halbtrocken- und Trockengrünlandes
79 Trocken-warmer Waldsaum
80 ÄCKER, ACKERRAINE, WEINGÄRTEN UND RUDERALFLUREN
82 Böschungen und Raine mit Wiesencharakter
83 Böschungen und Raine mit wärmeliebenden pannonischen Staudenfluren
84 Böschungen und Raine mit Ruderalcharakter
85 Strauch- und Gestrüppreiche Böschungen
86 Spontanvegetation ruderaler Offenflächen
87 Acker
88 Weingarten
89 GEHÖLZE DER OFFENLANDSCHAFT, GEBÜSCHE
90 artenarme, nitrophile Gebüsche und Hecken
91 artenreiche Hecken und Gebüsche
92 Feuchtgebüsche
93 Neophyten-Gehölz
94 Robinien-Gehölz
95 Baumhecken
96 Naturferne Baumhecken und Windschutzstreifen
97 Baumreihen und Alleen
98 Weichholzdominierter Ufergehölzstreifen
99 Edellaubbaumdominierter Ufergehölzstreifen
100 Naturferne Ufergehölzstreifen
101 landschaftsprägende Baumgruppen und Einzelbäume
102 Laubbaumfeldgehölz aus standortstypischen Laubbaumarten
103 Feldgehölz aus standortsfremden Baumarten
104 Streuobstbestand
105 Intensiv-Obstbaumbestand und Fruchtstrauchkulturen
106 Christbaumkulturen und Baumschulen
107 Energiewald
108 Sukzessionsgehölze
109 Grabenwald

200	Wald Trockenrasen-Erweiterung
201	Wald ohne Maßnahmen
202	Einzelbaum ohne Relevanz
110	**GEOMORPHOLOGISCH GEPRÄGTE BIOTOPTYPEN**
111	Naturhöhle
112	Natürliche Felswände mit und ohne Felsspaltenvegetation
113	Steinwall, Lesesteinriegel, Trockenmauer
114	**TECHNISCHE BIOTOPYPEN, SIEDLUNGSBIOTOPTYPEN**
115	Kiesgrube in Abbau
116	Steinbruch in Abbau
117	Stillgelegter Steinbruch
118	Stillgelegte Schotter- / Kies- / Sandgrube
119	Freizeit- und Sportanlage
120	Gehölz- und strukturreicher Garten, Park
121	Gehölz- und strukturarmer Garten, Park
122	Freie Begrünungen und Anpflanzungen
123	Scher- und Trittrasen
124	Friedhof
125	Unbefestigte Freifläche
126	befestigte Freifläche
127	Bauernhof, Einzelhaus, Kleingebäude, Scheunen, Speichergebäude
128	Einzel- und Reihenhausbebauung, geschlossene Siedlung, Gewerbe- und Industriegebäude
129	Deponien und Kompostieranlage, Kläranlagen
130	Straßen und Bahnstrecken
131	unbefestigte Straßen und Wege
132	Grabenwald und Baumbestände an Hohlwegen mit Sukzessionsgehölzen

Appendix 2: Changes in the frequency and average cover of the most abundant species in the data set.

N 1: number of occurrences in 1990/92, F 1: frequency in 1990/92, N 2: number of occurrences in 2011, F 2: frequency in 2011, Diff. N: change in the number of occurrences, AC 1: average cover in 1990/92, AC 2: average cover in 2011, Diff. AC: change in average cover. Average cover was calculated as the arithmetic mean of cover values among all 105 plots (including zero values). Species are ordered by decreasing Diff. N.

Species name	N 1	F 1	N 2	F 2	Diff. N	AC 1	AC 2	Diff. AC
Brachypodium pinnatum	21	20%	48	45%	27	1.92	5.62	3.70
Ranunculus acris	34	32%	46	43%	12	0.64	0.84	0.20
Holcus lanatus	30	28%	38	36%	8	3.79	2.15	-1.64
Ranunculus bulbosus	28	26%	35	33%	7	0.37	0.48	0.10
Arrhenatherum elatius	72	67%	78	73%	6	14.38	14.36	-0.03
Festuca pratensis	50	47%	56	52%	6	1.72	5.27	3.55
Medicago x varia	26	24%	26	24%	0	0.92	0.62	-0.30
Colchicum autumnale	39	36%	39	36%	0	0.96	1.30	0.34
Veronica chamaedrys	43	40%	43	40%	0	0.43	0.60	0.17
Rumex acetosa	48	45%	47	44%	-1	0.51	0.56	0.05
Taraxacum officinale agg.	41	38%	37	35%	-4	0.62	0.40	-0.22
Stellaria graminea	24	22%	19	18%	-5	0.28	0.22	-0.06
Pastinaca sativa	23	21%	18	17%	-5	0.41	0.48	0.07
Filipendula vulgaris	40	37%	34	32%	-6	0.72	0.63	-0.09
Onobrychis viciifolia	40	37%	34	32%	-6	0.91	0.96	0.06
Dactylis glomerata	94	88%	87	81%	-7	2.79	3.55	0.76
Silene vulgaris	22	21%	15	14%	-7	0.18	0.16	-0.03
Carex flacca	21	20%	14	13%	-7	1.77	0.32	-1.45
Lathyrus pratensis	62	58%	54	50%	-8	1.43	0.96	-0.47
Betonica officinalis	24	22%	16	15%	-8	0.50	0.19	-0.31
Heracleum sphondylium	33	31%	24	22%	-9	0.63	0.41	-0.22
Luzula campestris agg.	29	27%	20	19%	-9	1.22	0.34	-0.88
Campanula rapunculoides	22	21%	13	12%	-9	0.26	0.45	0.19
Trifolium montanum	44	41%	34	32%	-10	1.69	1.12	-0.57
Avenula pubescens	67	63%	57	53%	-10	6.03	2.12	-3.91
Trifolium repens	36	34%	26	24%	-10	1.33	0.34	-0.99
Trifolium pratense	78	73%	68	64%	-10	4.94	2.03	-2.91
Galium verum	25	23%	15	14%	-10	0.41	0.33	-0.08
Trisetum flavescens	64	60%	53	50%	-11	3.80	1.59	-2.21
Centaurea scabiosa	44	41%	32	30%	-12	1.44	0.76	-0.67
Cerastium holosteoides	27	25%	15	14%	-12	0.25	0.13	-0.13
Arabis hirsuta	24	22%	12	11%	-12	0.20	0.07	-0.13
Cirsium pannonicum	29	27%	16	15%	-13	0.88	0.28	-0.60
Poa pratensis agg.	76	71%	63	59%	-13	1.44	1.29	-0.15
Sanguisorba minor	24	22%	11	10%	-13	0.26	0.13	-0.14
Hypericum perforatum	25	23%	12	11%	-13	0.19	0.08	-0.11
Plantago lanceolata	85	79%	70	65%	-15	2.23	1.79	-0.45
Anthoxanthum odoratum	41	38%	25	23%	-16	1.72	1.16	-0.56
Buphthalmum salicifolium	39	36%	23	21%	-16	1.47	0.35	-1.13
Lathyrus sylvestris	21	20%	5	5%	-16	0.45	0.07	-0.39
Rhinanthus minor	54	50%	37	35%	-17	2.76	0.44	-2.31
Thesium linophyllon	38	36%	21	20%	-17	0.64	0.33	-0.31

Pimpinella saxifraga	48	45%	31	29%	-17	0.47	0.32	-0.15
Galium mollugo agg.	54	50%	37	35%	-17	1.36	1.71	0.35
Peucedanum cervaria	24	22%	7	7%	-17	0.31	0.42	0.11
Euphorbia cyparissias	35	33%	17	16%	-18	0.88	0.25	-0.63
Tragopogon orientalis	60	56%	42	39%	-18	0.65	0.34	-0.32
Primula veris	56	52%	38	36%	-18	0.83	0.56	-0.27
Myosotis arvensis	23	21%	5	5%	-18	0.27	0.05	-0.22
Carex caryophyllea	33	31%	14	13%	-19	1.02	0.38	-0.64
Lotus corniculatus	70	65%	51	48%	-19	1.50	0.73	-0.76
Centaurea jacea	69	64%	50	47%	-19	2.63	1.70	-0.92
Koeleria pyramidata	24	22%	4	4%	-20	0.46	0.06	-0.40
Anthyllis vulneraria	29	27%	9	8%	-20	0.88	0.13	-0.75
Crepis biennis	29	27%	9	8%	-20	0.74	0.10	-0.64
Helianthemum nummularium	29	27%	9	8%	-20	0.82	0.11	-0.71
Leontodon hispidus	68	64%	47	44%	-21	3.91	0.78	-3.13
Medicago lupulina	47	44%	26	24%	-21	2.13	0.38	-1.75
Ononis spinosa	45	42%	23	21%	-22	1.06	0.37	-0.69
Dianthus carthusianorum	43	40%	21	20%	-22	0.41	0.22	-0.19
Veronica arvensis	26	24%	4	4%	-22	0.25	0.03	-0.22
Tanacetum corymbosum	34	32%	12	11%	-22	0.44	0.13	-0.31
Salvia pratensis	87	81%	65	61%	-22	4.14	2.93	-1.22
Bromus erectus	90	84%	67	63%	-23	21.27	11.49	-9.78
Daucus carota	30	28%	6	6%	-24	0.27	0.03	-0.24
Vicia cracca agg.	78	73%	54	50%	-24	2.37	0.98	-1.39
Linum catharticum	37	35%	12	11%	-25	0.37	0.16	-0.21
Viola hirta	49	46%	24	22%	-25	0.61	0.44	-0.17
Festuca rupicola	72	67%	47	44%	-25	7.24	1.12	-6.12
Campanula patula	46	43%	21	20%	-25	0.43	0.17	-0.26
Briza media	49	46%	23	21%	-26	0.75	0.30	-0.45
Trifolium campestre	33	31%	7	7%	-26	1.45	0.10	-1.35
Achillea millefolium agg.	85	79%	58	54%	-27	0.91	0.66	-0.25
Knautia arvensis	79	74%	50	47%	-29	1.16	0.76	-0.40
Ranunculus polyanthemos	52	49%	21	20%	-31	0.84	0.23	-0.61
Leucanthemum vulgare agg.	62	58%	30	28%	-32	0.74	0.33	-0.42
Plantago media	57	53%	24	22%	-33	0.78	0.32	-0.46