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COORDINATOR Prof. Massimo Valoti

DIFFERENT HABITAT AND TAXA: VARIOUS APPROACHES AND THEIR IMPLICATIONS FOR A LONG-SIGHTED MANAGEMENT AND CONSERVATION

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TUTOR: Prof. Pietro Paolo Fanciulli

CANDIDATE: Dr. Gianmaria Bonari

CO-TUTOR: Dr. Claudia Angiolini

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General introduction

Proper management and conservation are urgent goals for both scientists and practitioners who deal with natural issues: those involved face new challenges daily. Unfortunately, management and conservation are not very reproducible in a lab because too many factors are involved. For instance, different habitats, scales and regions require calibrated approaches to avoid unintended complications. Climate, soil and human interference are a few elements that complicate the system. The purpose of this thesis is to unhinge some of these aspects through the use of different approaches applied in different ecological conditions, ranging from the semi-natural grassland of Central Europe to the coastal dune of the Mediterranean basin. Several tools were used to merge botanical, zoological and ecological knowledge, in order to serve nature conservation and provide concrete and useful management hints. In each chapter, a different stance on ecological problems linked to management and/or conservation issues have been addressed through the use of different techniques, offering challenging insights and new perspectives.

To attain these objectives, the thesis starts in the continental context of the White Carpathians Protected Landscape Area and UNESCO Biosphere Reserve (Czech Republic), a protected area famous for its grasslands with the globally highest fine-scale plant species richness. The effects of management on species richness and composition of both plants and animals were tested in relation to different management practices (mowing, grazing, abandonment and mixed management) for several years at several sites, clarifying the disagreements that have occurred among conservationists and practitioners to date. The thesis continues with a focus on the Mediterranean context. Here, the distribution patterns of understorey assemblages of coastal pine stands on sand dunes were studied, given the scarcity of literature due to scholarly disdain. Using more than a hundred plots along Italian coastlines in different pine forest types, community similarity and specificity was assessed in order to provide lacking management clues. Subsequently, focusing on a pine forest stand located in Southern Tuscany, the thesis aimed to solve another pivotal question, namely by investigating the concordance of species assemblages between vascular plants, oribatid mites and soil chemical properties with special attention to the role of vegetation structure (i.e. tree, shrub and herbaceous cover) for biological components. This part provides new answers about congruence among communities and following appropriate management practices to be fulfilled for communities. The last part, performed along a wide range of Tuscan coasts, deals with one of the most extreme habitats in the Mediterranean basin: coastal dunes. Here, the understanding of the response of plant species to

soil factors was estimated. This provides concrete proposals for the effective conservation of coastal habitats.

The results of the first chapter of this thesis are currently under review in Agriculture, Ecosystems & Environment (Elsevier, 5-Year Impact Factor: 4.233).

The results of the second chapter of this thesis are published in Forest Ecology and Management (Elsevier, 5-Year Impact Factor: 3.230): Bonari G., Acosta A.T.R., Angiolini C. (2017). Mediterranean coastal pine forest stands: Understorey distinctiveness or not?. *Forest Ecology and Management*, 391:19−28.

The results of the third chapter of this thesis are published in Arthropod-Plant Interactions (Springer, 5-Year Impact Factor: 1.612): Bonari G., Migliorini M., Landi M., Protano G., Fanciulli P.P., Angiolini C., 2017. Concordance between plant species, oribatid mites and soil in a Mediterranean stone pine forest. *Arthropod-Plant Interactions*, 11(1):1−9.

The results of the fourth chapter of this thesis are under review to Estuarine, Coastal and Shelf Science (Elsevier, 5-Year Impact Factor: 2.762).

Chapter 1

Management of semi-natural grasslands benefiting both plant and insect diversity: the importance of heterogeneity and tradition

Keywords
Carabidae; Conservation management; Lepidoptera; Orthoptera; Species richness; Vascular plant

Abstract

Biodiversity of grasslands depends on the management practices used. However, management systems suitable for one taxon, such as plants, can be detrimental to other taxa, such as insects, and vice versa. This study attempts to support conservation management planning by clarifying the effects of different grassland management practices on species richness and species composition of vascular plants, butterflies, moths, orthopterans and ground beetles, also taking into account the effects of climate and the landscape context. The study was performed in the White Carpathians Protected Landcape Area and UNESCO Biosphere Reserve (Czech Republic), which is famous for its grasslands with the globally highest fine-scale plant species richness. Different management practices (mowing, grazing, abandonment and mixed management) were applied for several years at 34 sites, where plants and different insect groups were subsequently sampled. Effects of management on species richness of different taxonomic groups were assessed using generalised linear models, whereas the effects on species composition were assessed using redundancy analysis. Management influenced species richness mostly in plants, butterflies and moths, but the effects of particular management practices on all species and species of regional conservation importance differed between these groups. The species richness of plants responded positively to mixed management and mowing, that of butterflies to mixed management and that of moths to mowing. The richness of plants and moths tended to respond negatively to grazing. Plant species composition was influenced by mowing, grazing and mixed management while that of moths by mowing and grazing. Orthopterans and ground beetles did not respond significantly to management. Our results indicate that conservation management should comprise the traditional practices that have historically contributed to the formation of the biological diversity of the semi-natural grasslands in the study area. In particular, grazing may not be optimal for traditional hay-meadows and mowing should be carried out similarly as in pre-intensive farmland, creating spatio-temporal heterogeneity rather than

uniformly cutting large grassland areas during a short period. In general, the optimal management should be heterogeneous, applying different practices in a mosaic or at different times during the season.

1. Introduction

Temperate semi-natural grasslands are among the most biodiverse ecosystems in the world (Wilson et al., 2012; Dengler et al., 2014; Chytrý et al., 2015). They have developed under century-long agricultural management, on which they continue to be dependent. In central Europe, semi-natural grasslands have been a traditional component of landscapes since pre-historic times (Hájková et al., 2011), but due to changes in farming intensity and land use, thousands of hectares of these grasslands have been destroyed or their biodiversity deteriorated in recent decades (Wesche et al., 2012). Their remnants have become endangered habitats (Janssen et al., 2016), demanding costly and well-considered management, since inappropriate management practices may harm biodiversity (Konvicka et al., 2008; Halada et al., 2011). Although the need for conservation management of these grasslands is widely accepted, the management practices that would be suitable for different groups of organisms are still under dispute among biologists and practitioners. Various cases of certain management practices supporting some taxonomic groups but having adverse effects on others have been presented (Pärt and Söderström, 1999; Kruess and Tscharntke, 2002a,b; Oertli et al., 2005), whereas evidence of similar responses to management across taxa is relatively rare (Öckinger et al., 2006; Köhler et al., 2016). In European nature conservation, plant requirements for grassland management have often been more stressed than the needs of animals, but conservation management must look beyond plant communities and integrate both floral and faunal components (WallisDeVries et al., 2002; Diacon-Bolli et al., 2012).

Despite an increasing focus of research on the management effects on grassland biodiversity (reviewed e.g. by Morris, 2000; van Klink et al., 2015; Török et al., 2016), only a few studies have evaluated the diversity of more than one group of organisms in semi-natural grasslands in eastern central Europe (e.g. Cremene et al., 2005; Báldi et al., 2013; Dvořáková et al., 2014; Sutcliffe et al., 2015), although some of these grasslands are global hotspots of fine-scale plant species richness (Wilson et al., 2012; Chytrý et al., 2015). The lack of knowledge about responses of different taxa to management calls for a proper conservation planning of management in these grasslands.

This paper assesses the effect of different management practices on plant and insect diversity using an extensive dataset sampled in the White Carpathian (*Bílé Karpaty*) Mountains, Czech Republic, central Europe. This region is unique for harbouring large areas of well-preserved semi-natural grasslands, which are remarkable for their extremely high plant species richness as well as valuable invertebrate fauna (Malenovský et al., 2012; Chytrý et al., 2015). Local nature conservation authorities focus on biodiversity preservation when practising grassland management (Jongepierová, 2008). However, there are persistent conflicts especially between botanists and entomologists as to the appropriateness of different management practices for the maintenance of the diversity of different taxa. Therefore, we test how different grassland management practices influence diversity and species composition of plants and several groups of insects, including butterflies, moths, orthopterans and ground beetles, taking into account the effects of climate and the landscape context.

2. Materials and methods

2.1. Study area

The study area comprises the Bílé Karpaty (White Carpathians) Protected Landscape Area and UNESCO Biosphere Reserve situated in the south-east of the Czech Republic along the border with Slovakia (48°49'–49°10'N; 17°15'–18°13'E; Figure 1).

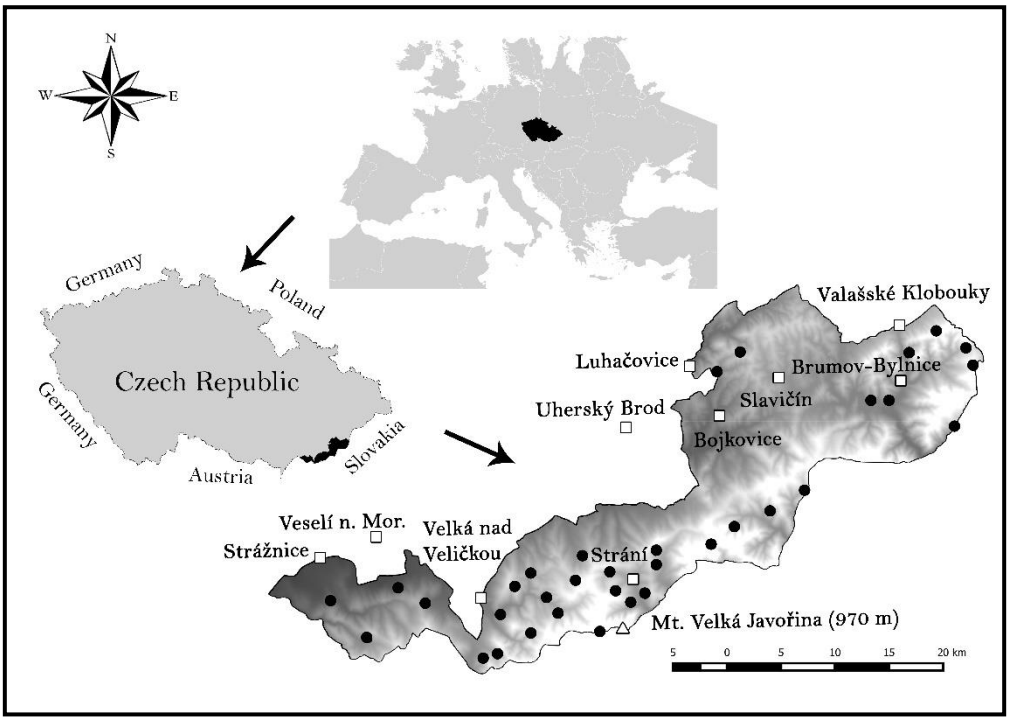

Figure 1 Study sites (black dots) in the White Carpathians (Bílé Karpaty) Protected Landscape Area and Biosphere Reserve (48°49'–49°10'N; 17°15'–18°13'E). Dark tones represent lowlands, lighter tones higher altitudes.

Climate varies with altitude, which ranges from 256 to 899 m (mean 469 m) at our study sites. The annual mean temperature at the study sites is 6.6–8.7 °C (mean 7.6 °C) and the annual precipitation is 533–1005 mm (mean 793 mm), peaking in June–July (Tolasz et al., 2007). Generally, precipitation increases and temperature decreases from the foothills situated along the north-western margins of the area towards the state border (Figure 1; Otýpková et al., 2011). The bedrock is flysch, a sequence of alternating sandstone and claystone layers of Lower Tertiary age, which supports the development of deep and heavy cambisols. They are generally base-rich, although they are more oligotrophic and acidic towards central and north-eastern parts of the area. Although woodlands cover more than 50% of the White Carpathians, especially at higher elevations, semi-dry meadows are the most conspicuous vegetation feature of this area (Jongepierová, 2008; Michalcová et al., 2014), hosting the highest species richness of vascular plants in the world at fine scales between 0.1 and 49 m^2 (Wilson et al., 2012; Chytrý et al., 2015). The prevailing grassland vegetation is *Brachypodio pinnati-Molinietum arundinaceae*, a transitional phytosociological association between the *Bromion erecti* and *Cirsio-Brachypodion pinnati* alliances (Chytrý, 2007). These meadows are semi-natural, spontaneously developing towards woodlands if regular management is abandoned. The meadows are probably thousands of years old (Hájková et al., 2011) and used to be mown for hay once a year in summer with occasional aftermath grazing in the late summer and autumn before the mid-20th century, in the era of pre-intensive agriculture. Currently, these meadows are subject to conservation management, which includes subsidised mowing (Jongepierová, 2008).

2.2. Field sampling and data

Vascular plants and four insect taxa (butterflies, moths, orthopterans, and ground beetles), were sampled at 34 grassland sites (min.-mean-max. area 1.5-8.8-70.7 ha) in 2006–2010. Sites were selected across the White Carpathians to represent the whole range of regional semi-natural grassland types (Figure 1; see Appendix A, Tables S1 and S2 for site characteristics and Supplementary text S1 for description of vegetation types). At each site, all vascular plants were recorded in a 1-ha plot in June to early July. In addition, four groups of insects were sampled at each site: butterflies (besides true butterflies also Rhopalocera, including burnet moths (Zygaenidae), and picture-wing leaf moths (Thyrididae), i.e. unrelated but ecologically similar taxa), orthopterans (grasshoppers, bushcrickets,

and crickets), moths (nocturnal macrolepidoptera) and ground beetles (Carabidae). Orthopterans and ground beetles were sampled on several dates in one growing season, butterflies and moths in two growing seasons. Butterflies and orthopterans were sampled by means of timed surveys, moths with light trapping and ground beetles by using pitfall trapping. Species abundances were classified on an ordinal scale. Lists of surveyed taxa, details of sampling methods and data processing, and nomenclature references are provided for each group in Appendix A, Supplementary text S2. To estimate the conservation value of the sites, regionally important species for the study area (including rare species and important bioindicators of natural habitats) were selected, based on national red lists (Grulich, 2012; Farkač et al., 2005) and local expert knowledge.

The following three sets of explanatory variables were recorded in the field or calculated using GIS for each site (Appendix A, Tables S3 and S4).

(1) Management was assessed as (i) 'grazing' (by sheep, cattle, both or, at one site located within a game preserve, by fallow deer, *Dama dama*); (ii) 'mowing' (manually or by tractor-pulled mowers once a year); (iii) 'abandonment' (areas where previous mowing or grazing has been terminated); (iv) 'mixed' (in most cases annual mowing of diffferent parts of the site in two or three terms with approximately three-week time-lags, often with deliberate one-year abandonment of small patches, or management practices alternating in time, e.g. mowing with aftermath grazing) (Figure 2).

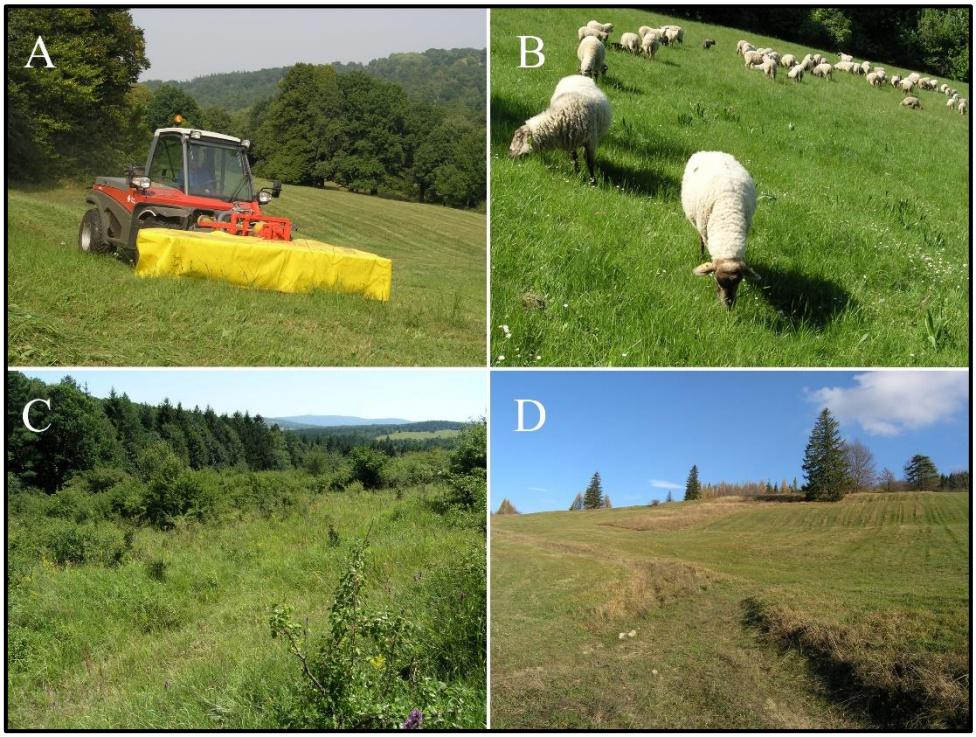

Figure 2 Grassland management practices in the White Carpathians: (A) mowing; (B) grazing; (C) abandonment; (D) mixed (in this case a mown meadow with deliberately left unmown patches).

Each management practice was given a score from 0 (not applied) to 2 (widely applied), allowing records of more than one management practice at each site. At each site the same management practice had been applied for at least five consecutive years preceding the sampling.

(2) Climate data, including mean annual temperature and total annual precipitation, were taken from digital climatic maps published by Tolasz et al. (2007). In addition, the topographic index of radiation for the growing season (April–September) was computed from a digital elevation model (DEM) of the Czech Republic with a resolution of 50 m following Rich et al. (1994) and Fu and Rich (2002).

(3) The landscape context, expressed by four variables, was tested as another potential driver of grassland diversity. First, we calculated percentage areas of four land-cover types (forest, grassland, arable land, settlements) within a circle of 1 km radius around the centroid of each site. Land-cover data were taken from a habitat map based on a field survey (scale 1:10 000; Härtel et al., 2009) and in the non-mapped (built-up or agricultural) areas from the remote-sensing-based CORINE land-cover map (Bossard et al. 2000; Appendix A, Table S5). Then, the Shannon diversity index was calculated based on the areas of different land-cover to quantify the landscape heterogeneity (Morris et al., 2014). Second, percentage grassland area was used to characterise grassland connectivity. Third, the number of grassland vegetation types (approximately at the level of phytosociological orders) recorded at each site in a field survey (Appendix A, Table S2) was used as a measure of local habitat heterogeneity. Fourth, percentage cover of woody species at each site, including a 25 m buffer zone, was visually estimated in orthophotos. All data processing was performed using the ArcGIS 10 software.

2.3. Data analysis

We modelled the response of species richness to the explanatory variables separately for each taxonomic group (plants, butterflies, moths, orthopterans and ground beetles), first for the number of all species and then also for the number of (i) open-country species excluding woodland habitat specialists recorded in the samples, (ii) all species of regional conservation importance, and (iii) open-country species of regional conservation importance. We used generalised linear models (GLM; McCullagh and Nelder, 1997) with quasi-Poisson distribution and log-link function, which allow the modelling of non-normally distributed, overdispersed count data (Lehmann et al., 2002). Variation partitioning (Borcard et al., 1992) among the three groups of predictors representing management,

climate and landscape context was calculated based on adjusted D^2, representing the amount of explained deviance adjusted for the number of parameters in the model (Guisan and Zimmermann, 2000). To compare the effects of different variables on species numbers, the total variation was decomposed into pure effects of management, climate and landscape context, shared effects of these groups of variables, and unexplained variation. After identifying the main groups of variables affecting species richness of each taxonomic group, gross and pure effects of particular management practices were assessed. For gross-effect analyses, the target management practice alone was used as a response variable, while all climate and landscape-context variables were included as covariables in the models. For pure-effect analyses, the target management practice was used as a response variable, while all other variables (the other management practices, climate and landscape-context variables) as covariables. Analyses were computed using the vegan v. 2.4-0 package (Oksanen et al., 2013) in R v. 3.3.1 (R Core Team, 2016). The R script used is available in Appendix A, Supplementary text S3.

An analogous approach was followed in the analyses of species composition, considering all species for each taxonomic group and a subset of open-country species. Effects of the three groups of variables (management, climate and landscape context) were analysed using redundancy analysis (RDA) with variation partitioning (Borcard et al., 1992). Adjusted partial R^2 was used to quantify the explained variation (Peres-Neto et al., 2006). Separate partial RDAs were performed for gross and pure effects of each management practice (effects of the other environmental variables were removed by defining them as covariables; to quantify pure effects, also the remaining management practices were set as covariables). Species with the strongest positive or negative response to the management practice were identified using species scores on the first ordination axis of separate partial RDAs. Monte Carlo tests with 9999 permutations were used to test the significance of the constrained axes. RDAs were calculated using CANOCO v. 5.04 (ter Braak and Šmilauer, 2012). Since the dataset contained only 34 replicates (grassland sites), we report also marginally significant ($P < 0.1$) effects for both species richness and composition.

3. Results

In the 34 surveyed grassland sites, 16,668 unique species-site records were obtained for 566 vascular plant species, 104 butterfly species, 656 moth species, 45 orthopteran species, and 71 ground beetle species (Table 1). Species matrices are provided in Appendix A, Tables S6–S10.

Table 1 Number of recorded species for individual groups.

	All species	Species of regional conservation importance	Open-country species	Open-country species of regional conservation importance
Plants	566	162	447	152
Butterflies	104	28	92	25
Moths	656	99	357	49
Orthopterans	45	11	42	11
Ground beetles	71	16	50	11

3.1. Species richness

Results of variation partitioning for total species richness (all species) differed among the taxonomic groups (Table 2).

*Table 2 Variation partitioning of the effects of management, climate and landscape context on the species richness of five taxa based on GLMs. All values are percentages of adjusted explained deviation (D^2); zero values indicate zero or negative adjusted D^2. Statistically significant results are given in bold (** < 0.01; * < 0.05; ° < 0.1). SRCI = species of regional conservation importance.*

	Plants	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
	All spp./ SRCI	**All spp./ SRCI**	**All spp./ SRCI**	**All spp./ SRCI**	**All spp./ SRCI**
Management	**18.3*/22.6***	**22.9***/2.3	**16.3°**/0	0.5/0	5.8/0
Climate	0.8/**8.8°**	0/1.5	0/4.7	**29.1****/7.7	0/0
Landscape context	0/0	7.0/6.1	0/0	0.4/0	0/0
(Management ∩ Landscape context) | Climate	0.1/1.2	0/0	8.4/6.7	0/4.7	0/4.3
(Management ∩ Climate) | Landscape context	1.1/6.8	0/0	6.7/9.2	0/11.5	4.5/5.5
(Climate ∩ Landscape context) | Management	0/0	0/2.2	2.9/0	7.6/2.4	5.6/6.8
Management ∩ Climate ∩ Landscape context	2.7/0	4.4/3.3	0/0	2.0/0	1.2/0.3
Total explained variation	**20.2°/28.3****	6.2/8.2	7.8/0	**25.9***/0	0/0

Plant, butterfly and moth species richness was affected mainly by management, orthopteran species richness by climate, while there were no significant trends for ground beetle richness. Models of gross effects of individual management practices on all species (Table 3) indicated a positive effect of mowing on plant and moth species richness while there was a negative effect of grazing on moth species richness. Abandonment had no effect on any taxon. Mixed management significantly increased plant and butterfly species richness. The positive effect of mixed management on plant and butterfly richness, and the positive effect of mowing on moth richness also remained in the models of pure effects. Variation partitioning for richness of species of regional conservation importance (Table 2) yielded significant results only for plants in which the effect of management prevailed and the effect of climate was relatively small. Models of effects of particular management practices on plant species of regional conservation importance (Table 3) revealed significant positive gross effects of mowing and mixed management and a negative gross effect of grazing, while no pure effects were significant.

*Table 3 Adjusted explained deviation (D^2) from GLMs of the effect of management practices on species richness for all species and species of regional conservation importance only in individual taxa. All values are in percentages of adjusted explained deviation (D^2), zero values indicate zero or negative adjusted D^2. Signs in square brackets originate from the corresponding regression coefficients. Statistically significant results are in bold (** < 0.01; * < 0.05; ° < 0.1). Gross effects are calculated after partialling out effects of climate and landscape context only; pure effects after partialling out effects of climate, landscape context and other management practices. NT = not tested because of non-significant effect of management (see Table 2).*

Management	**Plants**	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure
Number of all species					
Mowing	**[+]8.8°**/[-]0	[+]0/[-]4.4	**[+]11.7°/[+]10.7°**	NT	NT
Grazing	[-]2.6/[-]0	[-]0/[-]4.9	**[-]13.2***/[+]0	NT	NT
Abandonment	[-]0/[-]0	[+]0/[-]5.0	[+]0.4/[+]7.7	NT	NT
Mixed	**[+]22.8**/[+]16.9***	**[+]25.4**/[+]34.3****	[+]0/[-]0	NT	NT
Number of species of regional conservation importance					

Mowing	**[+]18.9****/[+]0	NT	NT	NT	NT
Grazing	**[-]13.0***/[-]0	NT	NT	NT	NT
Abandonment	[+]0/[+]0	NT	NT	NT	NT
Mixed	**[+]18.3****/[+]4.4	NT	NT	NT	NT

The results of analyses on the subsets of open-country species and open-country species of regional conservation importance were similar to those for all species and species of regional conservation importance, except for a marginally significant negative pure effect of grazing on open-country butterfly species richness and a non-significant response of open-country moth species richness to management (Appendix A, Tables S11 and S12).

3.2. Species composition

The plant and moth species composition weakly responded to management and climate, whereas the orthopteran composition responded to climate and the ground beetle composition to landscape context (Table 4).

*Table 4 Variation partitioning based on RDAs of total species composition of each taxon explained by three groups of environmental variables. All values are percentages of adjusted explained variation. Statistically significant results are given in bold (*** < 0.001; ** < 0.01; * < 0.05; ° < 0.1; 9999 permutations).*

	Plants	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
Management	**3.9***	0	**3.7°**	1.6	1.3
Climate	**2.9°**	0	**2.6°**	**7.7*****	0.3
Landscape context	2.3	0	0	0	**5.7***
(Management ∩ Landscape context) | Climate	1.2	0.9	0	1.2	0
(Management ∩ Climate) | Landscape context	0.3	0.9	0	0.5	<0.1
(Climate ∩ Landscape context) | Management	0.7	1.4	0.1	5.6	0
Management ∩ Climate ∩ Landscape context	0	0	0.6	0	1.0
Total explained variation	**10.3*****	0	**3.9°**	**15.5*****	**6.7***

Partial RDA tests of gross effects with a single management practice as explanatory variable indicated significant effects of mowing, grazing and mixed management on plant species composition and of mowing and grazing on moth species composition (Table 5).

Table 5 Adjusted explained variation (R^2) based on RDAs of total species composition of each taxonomic group. All values are percentages. Statistically significant results are given in bold (< 0.05; ° < 0.1; 9999 permutations). Gross effects are calculated after partialling out effects of climate and landscape context only; pure effects after partialling out effects of climate, landscape context and other management practices. NT = not tested due to non-significant effect of management (see Table 4).*

Management	**Plants**	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure
Mowing	**3.0***/0.7	NT	**2.1***/**2.5***	NT	NT
Grazing	**2.0***/0	NT	**2.1***/0.7	NT	NT
Abandonment	0/0	NT	0/1.1	NT	NT
Mixed	**2.1***/**1.5°**	NT	0/0.7	NT	NT

Partial RDA tests of pure effects of particular management practices showed an effect of mowing on moth communities and a marginal effect of mixed management on plant composition. Analyses of subsets of open-country species confirmed the effect of management on plant, and the effect of climate on orthopteran species composition, as well as gross effects of mowing, grazing and mixed management on plant composition (Appendix A, Tables S13 and S14). Plant and moth species with the strongest responses to each management practice with significant effect are reported in Appendix A, Tables S16–S23 and Figures S1–S8. A supplementary analysis (partial RDA tests of gross and net effects of single variables; Appendix A, Table S15) carried out to interpret the effect of the landscape context on the ground beetle species composition revealed a significant effect of local habitat heterogeneity (number of grassland vegetation types).

4. Discussion

Our study demonstrates that plants and different insect groups respond to grassland management practices in contrasting ways. Management was revealed as an important factor for the species richness of plants, butterflies and moths and for the species composition of plant and moth communities. However, it did not show any remarkable effects on communities of orthopterans or ground beetles. Effects of climate and landscape context on all these communities were negligible or smaller than the effects of management in the studied grasslands, except for orthopterans, whose species richness and composition mainly responded to climate, and ground beetles, whose species composition responded to landscape context. We will first discuss the effects of management (and partly of other factors) on taxonomic groups separately and then attempt to synthesise our results.

4.1. Plants

Management practices are well-known to alter plant composition and species richness of grasslands (e.g. Tälle et al., 2016). Our findings confirm a strong response of vascular plant communities to grassland management. In particular, we found that grazing had negative effects on the richness of species of regional conservation importance and also influenced plant species composition. Grazing is widely used as a conservation management tool in grasslands throughout Europe (WallisDeVries et al., 1998) and is considered to enhance plant diversity. Several highly endangered plant species are associated with pastures, such as dwarf gentians (*Gentianella* spp.), whose survival depends on extensive grazing (Bucharová et al., 2012). However, grazing is also known to reduce plant species richness in calcareous grasslands (Kormann et al., 2015) and is generally not recommended for traditionally mown sites, where recent introduction of other management practices can cause unwanted changes in species composition and decline in species richness. The study area of the White Carpathians has a long tradition of mowing meadows for hay dating back to at least as early as the 15th century (Húsek and Klvaňa, 1923; Jongepierová, 2008; Pajer, 2013). Our data confirm that the influence of this traditional management practice on plant species richness is, in contrast to grazing, generally positive. However, positive effects may occur especially if richness is measured in plots smaller than 100 m^2 (see also Klimeš et al., 2013; Chytrý et al., 2015), whereas heterogeneous management may have stronger positive effects on the richness of larger areas. We have showed that, in areas of 1 ha, mixed management with mosaic mowing of patches with approximately three-week intervals increases plant species richness more strongly than mowing alone. Mixed management probably supports plant species richness by providing niches for species with different requirements at a single site, including both those that are more supported by mowing and those that need temporal absence of disturbance for seed ripening (Diacon-Bolli et al., 2012). This finding is consistent with

the study by Babai and Molnár (2014), who showed that rotation of mowing dates of meadow tracts can preserve regionally important plants in the Romanian Carpathians. Actually, historical management of the White Carpathian grasslands also used to be patchy to some extent due to the division of land among multiple small owners who applied slightly different management practices involving different mowing dates, occasional grazing and occasional short-term abandonment (Jongepierová, 2008). The current mixed management can therefore be seen as a kind of continuation of the historical management that contributed to the development and maintenance of the extremely species-rich grasslands in this area. As our findings are consistent not only for total plant species richness and richness of open-country plants, but also for the richness of regionally important species which are the target of local conservation efforts, we conclude that such a mixed approach to grassland management meets conservation aims.

4.2. Butterflies

Most butterfly species avoid uniformly mown meadow plots and prefer heterogeneously managed ones, e.g. mown as strips or blocks (Cizek et al., 2012). Although mowing is necessary in the long-term to prevent succession, it causes direct mortality of eggs, caterpillars as well as adults, reduces available nectar sources and destroys shelters protecting butterflies against adverse weather and predators (Johst et al., 2006; Konvicka et al., 2008; Dover et al., 2010). Late-season mowing or leaving parts of the grassland unmown as a refuge can promote butterfly abundance and diversity (Valtonen et al., 2006; Brupacher et al., 2016). Intensive grazing also tends to have a negative effect on butterfly species diversity by disrupting the trophic interactions between plants and butterfly larvae or adults. A mosaic of grazed (at various intensity) and ungrazed grassland at both patch and landscape scales has therefore been recommended as an optimal strategy to maximise butterfly diversity in pastures (Kruess and Tscharntke, 2002b; Pöyry et al., 2006). Short-term abandonment of large grassland areas can be beneficial to many butterfly species (Balmer and Erhardt, 2000; Dover et al., 2011) but generalists may rapidly prevail at the expense of specialists (Stefanescu et al., 2009). Butterflies also differ from plants and many other invertebrates in large contrasts between the ecological requirements of their larvae and their adults. Many species therefore require a combination of resources found at different successional stages of vegetation at the local scale and, due to the high mobility of the adults, also at the landscape scale (Dennis et al., 2003). Our finding that mixed management has a positive effect on butterfly species diversity in the White Carpathians is therefore not surprising. Many studies have demonstrated that connectivity, landscape configuration and the type of surrounding habitats are important factors for butterflies and influence their diversity in a

complex way (Cozzi et al., 2008; Dover and Settele, 2009; Öckinger et al., 2012), but in our study these factors were not significant. Significant effects of grassland connectivity on butterfly species richness have been reported especially in highly fragmented landscapes (Schneider and Fry, 2001; Brückmann et al. 2010), whereas the effects of habitat quality in landscapes with large areas of grasslands tend to be more important than landscape effects (Krämer et al., 2012; Villemey et al., 2015). Our study area contains a relatively large proportion of semi-natural grasslands (the mean grassland cover within 1 km radius around our sites was 32%), hence fragmentation effects were probably low.

4.3. Moths

Moths are a species-rich group of phytophagous insects which has seldom been studied in grasslands in relation to management effects. In the White Carpathian grasslands, moth species richness and composition was mainly influenced by management, with mowing having a significant positive effect and grazing a negative effect on the total species number Both mowing and grazing also influenced moth species composition. However, no effect of management could be observed for species of regional conservation importance and open-country species. The positive effect of mowing on moth species richness was congruent with the mowing effect on plants. As many moth species are more or less host-specific in their larval stages, the response of moth richness to management may be indirect, mediated by their trophic dependence on plants and copying the response of plant richness to management. Flower-rich vegetation, typical of mown grasslands in the White Carpathians, probably also offers nectar attractive to adults of many moth species (Kuussaari et al., 2007; Šumpich and Konvička, 2012). However, the relationship between moth and plant richness in managed grasslands was not confirmed universally (Pöyry et al., 2006; Rickert et al., 2012). Also in our study, moths did not respond to increased plant diversity at sites with mixed management, as could be expected if their richness patterns mainly depended on plant richness patterns. It is possible that to some extent, higher moth richness of at mown sites could have been caused by a better visibility of light traps in the shorter sward, resulting into a higher attraction of moths from larger distances (Šumpich and Konvička, 2012). With respect to grazing, several studies have demonstrated that Lepidoptera are less tolerant to grazing than plants and so their species richness declines at intensively grazed sites (Kruess and Tscharntke, 2002b, Pöyry et al., 2006, Kuussaari et al., 2007, Littlewood, 2008; Rickert et al., 2012). Indeed many moth species were negatively affected by grazing in our study, particularly species living in litter and some grass- and legume-feeders whose host plants are selectively grazed by sheep and cattle. Still some species preferred grazed sites (Appendix A, Table S20, Figure S5).

These results are in agreement with previous studies showing that pastures, despite being species-poorer than ungrazed sites, are an important habitat for moth species associated with certain host plants (Pöyry et al., 2005, 2006) or overwintering in the egg stage (Littlewood, 2008). We did not find any significant effects of temporary abandonment on moth communities in the White Carpathians. However, other studies from central and eastern Europe have reported a high moth richness and distinct species composition in abandoned grasslands as a result of better availability of shelter in this structurally diverse vegetation and more feeding niches, e.g. in accumulated litter, which can compensate for the decrease in plant species richness (Cremene et al., 2005; Baur et al., 2006; Šumpich and Konvička, 2012).

4.4. Orthopterans

In contrast to butterflies and moths, most orthopterans are generalist feeders (mostly herbivores or omnivores) which do not strictly depend on the presence of certain host plant species (Joern, 1979). However, they are influenced by the vegetation structure, which depends on grassland management (Guido and Gianelle, 2001). Somewhat surprisingly, we did not find any significant effect of management on species richness or composition of Orthoptera in the White Carpathian grasslands. Similar results were found in studies from the Swiss Alps (Oertli et al., 2005) and Bulgaria (Senn et al., 2011). This can probably be explained by the low-intensity use of the studied grasslands. Oertli et al. (2005) suggested that the effect of land use on orthopteran species richness depends, besides management practice, on the disturbance gradient included in the study. Intensive grassland management (fertiliser application, mowing more than once a year, high stocking densities and permanent grazing) usually leads to a decrease in species richness of the orthopteran communities in both hay-meadows and pastures (Kruess and Tscharntke, 2002b, Marini et al., 2008; Fabriciusová et al., 2011). Because of their relatively large size and limited mobility, orthopterans are particularly vulnerable to large-scale mowing, which kills them during hay harvesting, subsequently causes high sward temperatures, and also increases the risk of predation by vertebrates (Gardiner and Hassall, 2009; Humbert et al., 2010). As for butterflies, these negative effects can be counteracted by preserving patches of temporarily uncut grassland (Cizek et al., 2012; Buri et al., 2013). Also similar to butterflies, some orthopteran species require a combination of different ecological conditions at a site, such as bare ground, short sparse vegetation, and taller dense grassland (Cherrill and Brown, 2006). Such small-scale heterogeneity is more likely to be found in pastures, as is confirmed by some studies concluding that low-intensity grazing is a more suitable practice than mowing for the conservation of grassland Orthoptera (Fabriciusová et al., 2011; Weiss et al., 2013). However, the

species-specific and region-specific response of Orthoptera to grazing (Batáry et al., 2007b; Rada et al., 2014) makes it hard to make a simple generalisation. Some species prefer mown meadows, thus both grazing and mowing can contribute to the overall diversity and should be combined at the regional level (Oertli et al., 2005; Senn et al., 2011). Abandonment of grassland management can increase orthopteran diversity in the short term but this is followed by a decrease after several years due to changes in vegetation structure and woody plant encroachment (Marini et al., 2009). Orthopterans were the only group in our study which showed distinct responses to climatic factors for most biodiversity measures examined. Mesoclimate clearly needs to be considered in the conservation of this group together with grassland management (Weiss et al., 2013).

4.5. Ground beetles

We could not find any significant effects of management on species richness and composition of ground beetles in the White Carpathians. As in the orthopterans, this may be partly explained by the relatively low intensity of mowing and grazing at our study sites and independence of ground beetles of the occurrence of particular plant species. Ground beetles are mostly polyphagous predators or opportunistic seed-consumers (Lövei and Sunderland, 1996) and respond more strongly to vegetation structure than to plant taxonomic diversity (Brose, 2003). Intense grazing leading to a short sward, a uniform vegetation structure, reduced litter and a disturbed soil surface reduce the abundance of large flightless epigeic species such as *Carabus* spp. In contrast, grazing favours smaller mobile species, particularly macropterous generalists, some specialised predators preferring a more open sward, as this facilitates hunting, and species preferring drier conditions (Blake et al., 1996; Dennis et al., 1997; Cole et al., 2006). Similar patterns occur in strongly disturbed habitats in general, such as grasslands subject to multiple cuts (Ribera et al., 2001; Rainio and Niemelä, 2003). However, most studies found no differences in ground beetle species richness between intensive and extensive pastures (Söderström et al., 2001; Cole et al., 2006; Batáry et al., 2007a) and some even indicated a positive correlation of species richness with management intensity (Grandchamp et al., 2005; but see Gardner et al., 1997 for a reversed result). Few studies compared ground beetle assemblages in meadows and pastures directly: mown sites generally contained more species than grazed ones, but had partly different compositions (Grandchamp et al., 2005; Gobbi et al., 2015). Grassland abandonment is generally considered to be negative for the conservation of open-country ground beetle assemblages because an increasing cover of woody plants adversely changes their habitat, although the abandonment can initially have a positive effect (Taboada et al., 2011; Schirmel et al., 2015). The species richness of ground beetles should benefit from spatio-temporally varied management such as

rotational grazing (Dennis et al., 1997) or mosaic mowing (Cizek et al., 2012). While the response of ground beetles to management was insignificant, their species composition was influenced by landscape-context variables, especially by habitat heterogeneity. The heterogenous sites in our study generally included, besides the prevailing mesic or semi-dry grasslands and scattered scrub and small woodland, also patches of spring fens or wet meadows (Appendix A, Table S2). As soil moisture is an important environmental factor for ground beetles (Gardner, 1991; Blake et al., 2003; Yanahan and Taylor, 2014), this heterogeneity in moisture created gradients in species composition of ground beetle communities, but did not affect species richness.

4.6. Responses to management across taxonomic groups: a synthesis

We found only partial congruence in responses of individual taxonomic groups to different management practices in the White Carpathian semi-natural grasslands, as summarised in Table 6.

Table 6 Management recommendations for each taxon in historically mown low-intensively managed White Carpathian grasslands. ++ strongly recommended management; + recommended management; - unrecommended management. Recommendations in brackets are not supported by this study but based on literature; other ones are based on this study.

Management	**Plants**	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
Mowing	+	(-)	+	(-)	(+)
Grazing	-	-	-	(+)	(+)
Abandonment	(-)	(-)	(+)	(-)	(-)
Mixed (mosaic mowing with short-term abandoned patches)	++	++	(+)	(+)	(+)

Mowing for hay, performed once a year in late spring or summer, is positive for maintaining a high species richness of plants and moths but, based on ample evidence in the literature, it may be harmful to butterflies, orthopterans and many other smaller and less mobile arthropods not addressed in our study, such as spiders, leafhoppers, true bugs, endophytophagous insects and their parasitoids (Morris and Lakhani, 1979; Völkl et al., 1993; Bucher et al., 2016). It is probably mainly due to the current practice of cutting grasslands in large areas during a very short time period by tractor-pulled mowers. In recent decades, such a practice has replaced the traditional but labour-intensive manual mowing with scythes. However, the negative effects of mowing can be mitigated by spatial and temporal diversification of the mowing regime as well as leaving parts of meadows uncut to serve as refuges until autumn or the next growing season (Cizek et al., 2012; Buri et al., 2013; Brupacher et al., 2016). This would also support generative reproduction of many plant species with seeds ripening in late summer (Babai and Molnár, 2014).

Furthermore, we found that in the studied grasslands grazing is generally not the best management practice for plants, at least those of regional conservation importance, and some insect groups (moths and open-country butterflies). This contradicts the general results of a recent meta-analysis by Tälle et al. (2016), who found that grazing had generally a more positive effect on the conservation value of semi-natural grasslands than mowing, although the effect sizes were small and varied among grassland types, regions and taxonomic groups. It is important to emphasise that both grazing and mowing tend to have positive effects in areas and at sites where they were used either in the period before agricultural intensification or in more recent history. This seems to apply to the White Carpathians, where mowing, previously often combined with aftermath grazing, has occurred for centuries (Húsek and Klvaňa 1923; Jongepierová, 2008; Pajer 2013). Similarly to mowing, the prevailing effect of grazing on arthropod diversity is negative because of unintentional predation and increased disturbance of arthropods by grazing animals, depletion of resources and simplification of habitat structure. However, grazing can increase arthropod diversity if it increases the variation in plant species composition or habitat heterogeneity to such a degree that it can compensate for the direct negative effects (van Klink et al., 2015). This enhancement of environmental heterogeneity can be achieved by rotational grazing with periods of temporary abandonment or grazing at a low stocking rate (Morris, 2000; WallisDeVries et al., 2002; van Klink et al., 2015; Köhler et al., 2016). Moreover in the long term, grazing supports other sets of plant and animal species than mowing. Some invertebrate taxa are directly dependent on grazing animals, such as dung-dependent beetles and dipterans or blood-, secretion- or tissue-feeding parasites (van Klink et al., 2015). Low-intensity grazing is the optimal practice for conservation of some highly threatened plants and animals which in the White Carpathians include the Autumn Dwarf Gentian (*Gentianella amarella* subsp. *amarella*),

the Large Blue butterfly (*Phengaris arion*), and the Rattle Grasshopper (*Psophus stridulus*), just to mention three flagship species (Jongepierová, 2008). For all these reasons, grazing should be applied in the White Carpathian grasslands at the sites where it has been used historically or where it supports certain threatened species. However, it should not be introduced to sites which were traditionally mown.

Because of the disturbing nature of both mowing and grazing, a short-term abandonment of grassland management often leads to higher abundances and a higher species richness of grassland arthropods (Balmer and Erhardt, 2000; Marini et al., 2009). In our study, temporal abandonment of small patches as part of a mixed management practice had positive effects on butterflies and plants, and evidence from the literature also suggests its importance for the conservation of moth diversity (Cremene et al., 2005; Šumpich and Konvička, 2012). However, the optimal length of absence of grassland management can vary strongly between plant communities depending on e.g. productivity and dominant grass species. In the White Carpathian grasslands, even less than three years of abandonment has been shown to cause loss of plant diversity in small plots, especially in more productive habitats (Klimeš et al., 2013). This suggests that grassland parts left for short-term abandonment as a means of conservation management should be carefully selected and the management should be resumed relatively soon.

5. Conclusions and implications for conservation

As already stated by Morris (1969), there is no single method of managing grasslands to maintain habitats of all or even many of the characteristic plant and animal species. We studied species-rich semi-natural grasslands which were traditionally not fertilised and mostly mown once annually with occasional aftermath grazing. Although our results reveal differences in the response of plants and particular insect groups, they also indicate that it is possible to reconcile management needs in such grasslands. Mosaic mowing combined with short-term abandonment of small meadow patches, and possibly also occasional aftermath grazing, is the management practice that simultaneously supports diversity of plants, butterflies and moths, while any management seems to have negligible effects on the diversity of orthopterans and ground beetles. In contrast, grazing and long-term abandonment of larger areas have a negative effect on the diversity of most of these groups in the study area.

These findings are important for management plans of grassland areas which are the main focus of conservation efforts in the White Carpathians Protected Landscape Area and Biosphere Reserve. In

addition to this direct application, a more general lesson learned from this study is that conservation management should imitate the management that historically contributed to the development of the diversity that we are conserving today. In particular, grazing may not be a suitable management practice at traditionally mown sites. Moreover, any management should create environmental heterogeneity at various scales (Diacon-Bolli et al., 2012). For example, mowing should be practised similarly to pre-intensive farmland (Babai and Molnár, 2014), i.e. different patches of large meadow tracts should be mown on different dates and some patches should temporarily be left unmown to secure the survival of various invertebrates and also the generative reproduction of a range of plant species with different phenology.

Chapter 2

Mediterranean coastal pine forest stands: Understorey distinctiveness or not?

Keywords:

Canopy cover; Dunes; Italy; Plant species assemblage; Sea-inland gradient; Vegetation

Abstract

A common perception of plantation forests is that they constitute an "ecological desert" and that is why they are often disdained by scholars. Distribution patterns of understorey assemblages of coastal pine stands on sand dunes are still little known, despite such forests being widespread along the Mediterranean coastline, particularly in Italy. The purpose of this study of 167 plots along Italian coastlines was to analyse whether similar communities and specific species pools occur in different pine forest types dominated by *Pinus pinea*, *P. halepensis* or *P. pinaster*. Multivariate analysis was used, including the effects of sea-inland gradient and of pine canopy cover. The results indicated that pine forests show the lack of a clear floristic differentiation among different pine forest types at community level. Nevertheless, psammophilous species of coastal dunes occurring mostly in *P. halepensis* stands, and forest species mainly being linked to *P. pinea* stands, indicated a distinctiveness at species level probably related to different pine ecology as well as to the coastal zonation along the sea-inland gradient, already well-known for non-forested dunes. Thus, the natural zonation of coastal vegetation is maintained, although higher pine canopy cover affected the understory species assemblages, both herbaceous and woody, in a negative way. In light of this, species-specific management strategies are not recommended for Mediterranean coastal pine forests, and a long-sighted management should take into account actions considering floristic differentiation linked to coastal vegetation zonation. These findings should not be disregarded since they have implications for management planning and conservation and because understoreys of Mediterranean pine plantations, with a species reservoir of unknown value, have often hitherto been overlooked.

1. Introduction

Forest stands with dominance of stone pine, Aleppo pine and maritime pine (*P. pinea*, *Pinus halepensis*, *P. pinaster*) occur along almost all the low sandy coast of the Italian peninsula (Biondi et al., 2009), extending from the first back dune to the last settled innermost dune environment (Figure 3).

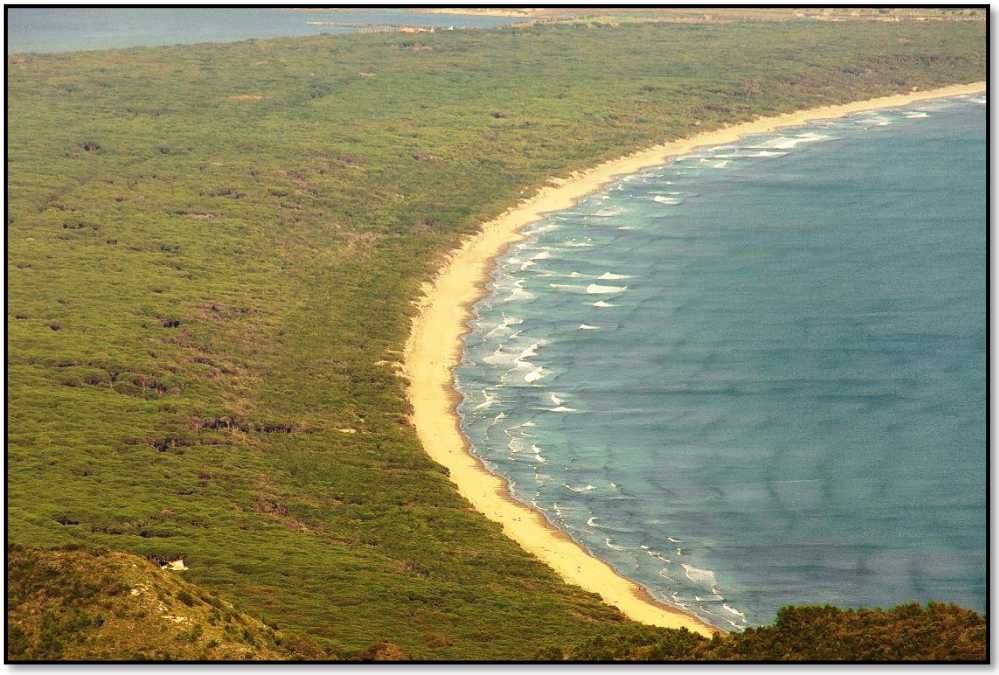

Figure 3 Mediterranean pine coastal forest at Feniglia Dune (Italy).

Italian coastal pine forest vegetation, autochthonous or derived from ancient plantations, consists mainly of *P. pinea* or *P. halepensis* (Biondi and Blasi, 2015). Historically, the primary role of coastal pine forest stands was as a shelterbelt to protect cropland from salty sea spray and for production of pine nuts, timber and resin. These forests were mainly planted in the second half of the twentieth century or later and were maintained by humans for coastal defence against waterproofing and soil erosion (Calama et al., 2003). They are well known for their rehabilitation capacity in Mediterranean dunal environments (see Bellarosa et al., 1996), as well as for recreational uses (Cutini et al., 2013) and carbon storage and sequestration services (Drius et al., 2016). Planted forests that were established a long time ago are more likely to be a habitat for biodiversity, although a common perception is that they are "ecological deserts" (Brockerhoff et al., 2008). At European level they are included in "Coastal brown dunes covered with natural or almost natural thermophilous pines" (EUNIS Habitat Type Code B1.74), as "Mediterranean coniferous coastal dune woodland" in the European Red List of Habitats (Type Code B1.7d; Janssen et al., 2016) and in the 92/43 EEC Directive Habitat as priority habitat 2270 ("Wooded dunes with *P. pinea* and/or *P. pinaster*"), also

including P. halepensis forests (Biondi et al., 2009). However, in recent decades, environmental concern about sandy coasts and associated pine forest have increased, mainly due to direct and indirect effects of human activities, such as coastal erosion (Raddi et al., 2009), salinisation of groundwater (Antonellini and Mollema, 2010; Zanchi and Cecchi, 2010), trampling (Santoro et al., 2012) and urban sprawl (Reina-Rodríguez and Soriano, 2008; Malavasi et al., 2013). These threats have been particularly intense in the last 50 years in countries bordering the Mediterranean Sea (Curr et al., 2000).

The flora of coastal pine forests has rarely been studied because artificial forests are not highly esteemed from a conservation viewpoint (Brockerhoff et al., 2008). Although pines are the most common plantation species worldwide (about 20% of total plantation area) (FAO, 2001), they have attracted relatively little in plant community research compared with other forest types. However, pine-climate interactions (Mazza et al., 2011; Mazza et al., 2014; Cutini et al., 2015), fire practices and their effects (Fernandes and Botelho, 2004; Rigolot, 2004; Fernandes et al., 2008) and dendrochronology are widely debated in the scientific literature (Calama et al., 2003 ; Calama and Montero, 2005). Although they are threatened like other dunal plant communities, the understoreys of these forests and the processes that drive them are still largely unknown and the importance of plantation forests for biodiversity conservation goals is a controversial issue.

Our primary objective in this study was to understand whether pine forests with different dominant pine species can harbour a peculiar understorey species pool. We assumed that overstorey composition and structure influence understorey plant communities through modification of resources including light and soil (Messier et al., 1998; Légaré et al., 2001), with some species having special affinities for a particular overstorey type (Bartels and Chen, 2010). We analysed also the effects of sea-inland gradient and pine canopy cover on the underlying layers. Major questions were: (i) Does vegetation associated with a pine forest type form distinct communities? (ii) Are some plant species more likely to occur in one pine forest type than others? (iii) How do distance to coastline and pine canopy cover affect pine understorey species assemblages?

In this way, the present study aims to investigate whether species-specific management is required for forests dominated by different pine species and their understoreys, as a guide for vegetation management in Mediterranean coastal areas.

2. Materials and methods

2.1. Pine forest-types

For data collection, we considered the EU Directive definition of Habitat 2270 "Wooded dunes with P. pinea and/or P. pinaster" that also includes P. halepensis forests (Biondi et al., 2009). We then used data of three different pine forest-types dominated by: (i) Stone pine (*Pinus pinea*); (ii) Aleppo pine (*Pinus halepensis*); (iii) Maritime pine (*Pinus pinaster*).

Pinus pinea is scattered throughout the Mediterranean basin, mainly in coastal areas. In Italy this "umbrella-shaped" tree is the icon of Italian coastal forests (Mazza et al., 2014) and it is reported as native to Liguria, Tuscany, Molise and the major islands, i.e. Sicily and Sardinia (Conti et al., 2005), although there is little evidence of its nativeness (Abad Viñas et al., 2016). Pinus halepensis is largely present in the Western sector of the Mediterranean basin and it is the most widely distributed Mediterranean pine. In Italy the species is recognized as native to all regions except the Alps (Conti et al., 2005), although it has been widely planted (Mauri et al., 2016). P. pinaster has a western Mediterranean distribution; this medium-size pine mainly occurs in north and central Italy. Its presumed native distribution includes Liguria, Tuscany, Lazio and the major islands (Conti et al., 2005).

2.2. Study area

The study area included pine forests established on dunes along the coasts of the Italian peninsular. The forests occur in six admistrative regions on the coasts of the Tyrrhenian (Toscana, Lazio and Campania) and Adriatic seas (Emilia-Romagna, Molise and Puglia), including much of the distribution of pine stands in the Italian peninsular. The sites ranged about from 0 to 5 m a.s.l. and phyto-climate depends mostly on latitude, ranging from Temperate to Mediterranean, passing through transition zones (Blasi and Michetti, 2007). The study area comprises mainly calcareous sediments, although aeolian deposits also occur from place to place (Geoportale Nazionale, 2015).

2.3. Data collection

For the purpose of the present study, field sampling in *Pinus pinea* stands was performed in 2014–2015, whereas an existing database of coastal dune vegetation (Acosta et al., 2009; Malavasi et al., 2016) was mainly used for *P. halepensis* and *P. pinaster* stands. Firstly, only plots with at least one of the pine species (*Pinus pinea*, *P. halepensis* or *P. pinaster*) were used, because our interest was the role of pines. Secondly, only plots on sandy soil were included in the dataset. Thus, a dataset based on 167 plots (2 × 2 m; 94 ascribed to *Pinus pinea*, 65 to *Pinus halepensis*, and 8 to *Pinus pinaster*) was defined. Each plot was assigned to a pine forest type in relation to the pine species dominant in each plot. Plant values were cover percentages of each species between 0 and 100. Distance between georeferenced plot and coastline, used as a proxy of sea-inland gradient, was determined by GIS. The study did not involve any experimental manipulations or disturbance of naturally developed relationships. Observed patterns should therefore reflect long-term plant-ecological interactions. The focal species of dunal vegetation were identified and selected using the list of diagnostic and characteristic species in the "Italian Interpretation Manual of the 92/43/EEC Directive Habitats" (Biondi et al., 2009; Biondi and Blasi, 2015). Autochthonous species names are according to Conti et al. (2005), alien species names are according to The Plant List (2013).

2.4. Data analysis

Evaluation of species composition distinctiveness in each forest type was performed using the following techniques:

(1) Multi-response Permutation Procedure (MRPP), a non-parametric multivariate procedure for testing the hypothesis of no difference in species composition between two or more groups of plots chosen a priori (McCune and Grace, 2002). A weighted mean within-group distance in species space is calculated using Sorensen distance. MRPP consists of two statistical tests: the A Statistic estimates within-group homogeneity and the T Statistic measures between-group separability. Higher A statistic values (maximum value 1) indicate a high degree of homogeneity within groups while a large negative T value (≤ -10.0) indicates high separability between groups. The null hypothesis was assessed by a Monte Carlo permutation procedure with 999 permutations;

(2) Non-Metric Multidimensional Scaling (NMDS) based on Euclidean distance, used to investigate community patterns without data transformations;

(3) Indicator species analysis (IndVal), performed to find species significantly associated with each forest type via 4999 randomization tests (Dufrené and Legendre, 1997).

To investigate whether sea-inland gradient and pine canopy cover significantly influenced understorey species distribution in coastal pine forests, two hybrid constrained CCAs were performed, with the Log (X+1)-transformed variable 'Distance'. The significance of the constrained axis was tested by a Monte Carlo randomization method, using 999 permutations. To test species response to sea-inland gradient and pine cover, for species with more than ten occurrences in the dataset, including pines, we used General Additive Models (GAM) with binomial distribution, logit link function, 2.0 df (see Yee and Mitchell, 1991; Hájková et al., 2008; Ilunga wa Ilunga et al., 2013; Dyakov, 2016) and the quasi-distribution approach for modelling overdispersed data. GAMs were chosen because they assume a non-linear relationship between the response and each explanatory variable. Binomial distribution data was treated as binary. MRPP and IndVal analyses were performed using the software package PCORD 6.0 (McCune and Mefford, 2011), whereas NMDS, CCAs and GAMs were calculated using CANOCO v. 5.03 (ter Braak and Šmilauer, 2012).

3. Results

Twenty-eight percent (74 out of 269; Appendix B, Table S24) of all coastal pine stand species were focal for dune habitats. The MRPP results using the data set excluding the pine species, showed few differences between vegetation plots when forest types were compared. Although the T statistic was negative (−10.78) and statistically significant ($p < 0.001$), within-group average distance was high (Sorensen distance = 0.94). In addition, the A statistic, a measure of within-group homogeneity, was very low (0.014).

The forests, classified a priori using dominance of different pine species, were grouped by NMDS diagram into a single cluster, as shown in Figure 4.

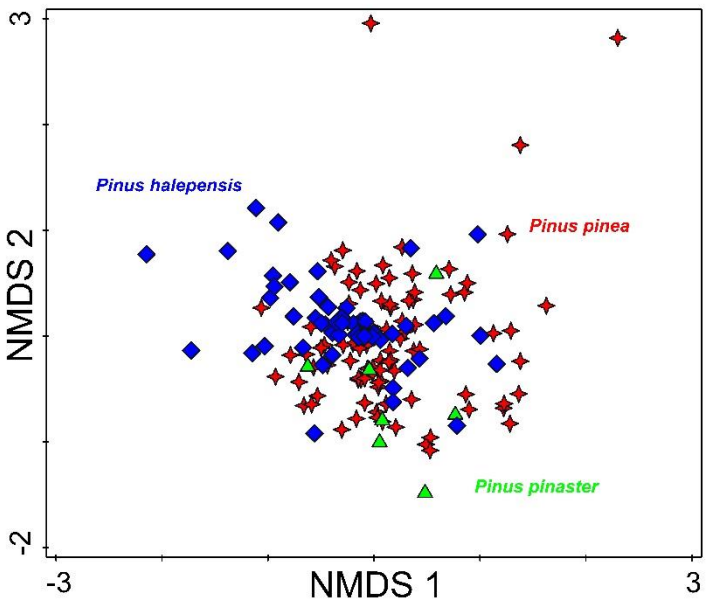

Figure 4 NMDS diagram of plots excluding pine canopy cover data. Colors indicate the dominant pine species. Red stars are Pinus pinea dominated plots, blue diamonds are P. halepensis dominated plots and green triangles are P. pinaster dominated plots.

The biplot (Figure 4; final stress = 0.18482), showed that the first three axes explained 100% of community variation (axis 1 and axis 2 captured 38.8% and 34.2% of the variance, respectively) and indicated unclear separation of plots dominated by different pine species.

IndVal to detect affinity of species with the three pine forest types revealed a low percentage of indicator species (10.8%) among the total number of species (Table 7; McCune and Grace, 2002).

Table 7 IndVal (IV) of significant species for different pine forest types and the respective significance levels (p). Species are sorted in alphabetical order.

Dominant species	Indicator species	IV	p
Pinus pinea	*Arum italicum*	8.4	0.0484
(p = 0.001)	*Brachypodium sylvaticum* ssp. *sylvaticum*	13.8	0.0032
	Carex flacca	11.7	0.0072
	Carex distachya	8.5	0.0192

Dominant species	Indicator species	IV	p
	Clematis flammula	9.7	0.0280
	Cyclamen repandum	7.4	0.0374
	Euphorbia peplus	10.6	0.0104
	Geranium purpureum	11.7	0.0066
	Trachynia distachya	7.4	0.0338
Pinus halepensis	*Ammophila arenaria* ssp. *australis*	9.4	0.0032
(p = 0.001)	*Artemisia campestris* ssp. *glutinosa*	10.9	0.0012
	Cyperus capitatus	15.6	0.0004
	Echinophora spinosa	6.2	0.0226
	Elymus farctus ssp. *farctus*	21.9	0.0002
	Elymus repens ssp. *repens*	7.8	0.0072
	Erigeron canadensis	6.2	0.0200
	Erodium laciniatum	12.5	0.0002
	Eryngium maritimum	6.2	0.0216
	Euphorbia terracina	17.2	0.0002
	Medicago marina	10.9	0.0006
	Ononis variegata	9.4	0.0034
	Phleum arenarium ssp. *caesium*	12.5	0.0006
	Reichardia picroides	17.1	0.0004
	Silene canescens	17.2	0.0002
	Silene vulgaris	17.7	0.0004
	Sixalix atropurpurea	20.9	0.0002
	Sporobolus virginicus	25.0	0.0002
	Verbascum niveum ssp. *garganicum*	12.5	0.0004
	Vulpia fasciculata	17.2	0.0002
Pinus pinaster (n.s.)	/	/	/

Indicator species for *P. pinea* forest type numbered 9 (3.4%) and were mainly related to forest on stabilized dunes, including *Brachypodium sylvaticum* ssp. *sylvaticum* and *Carex distachya*. Indicator

species for *Pinus halepensis* forest type numbered 20 (7.4%), and were typical pioneer psammophilous species, such as *Ammophila arenaria* ssp. *australis* and *Medicago marina*, mostly associated with the forward part of the dune series. No significant indicator species for *P. pinaster* forest type were detected.

Hybrid CCA (Figure 5) with first axis constrained by sea distance significantly discriminated three clusters of coastal pine forest species: typical dunal species closer to the sea, such as *Elymus farctus* ssp. *farctus* and *Vulpia fasciculata*, species typical of Mediterranean maquis at intermediate distance, such as *Phillyrea angustifolia* and *Hedera helix*, and generalist species at greater distances from the sea, such as *Bellis perennis* and *Cerastium glomeratum*.

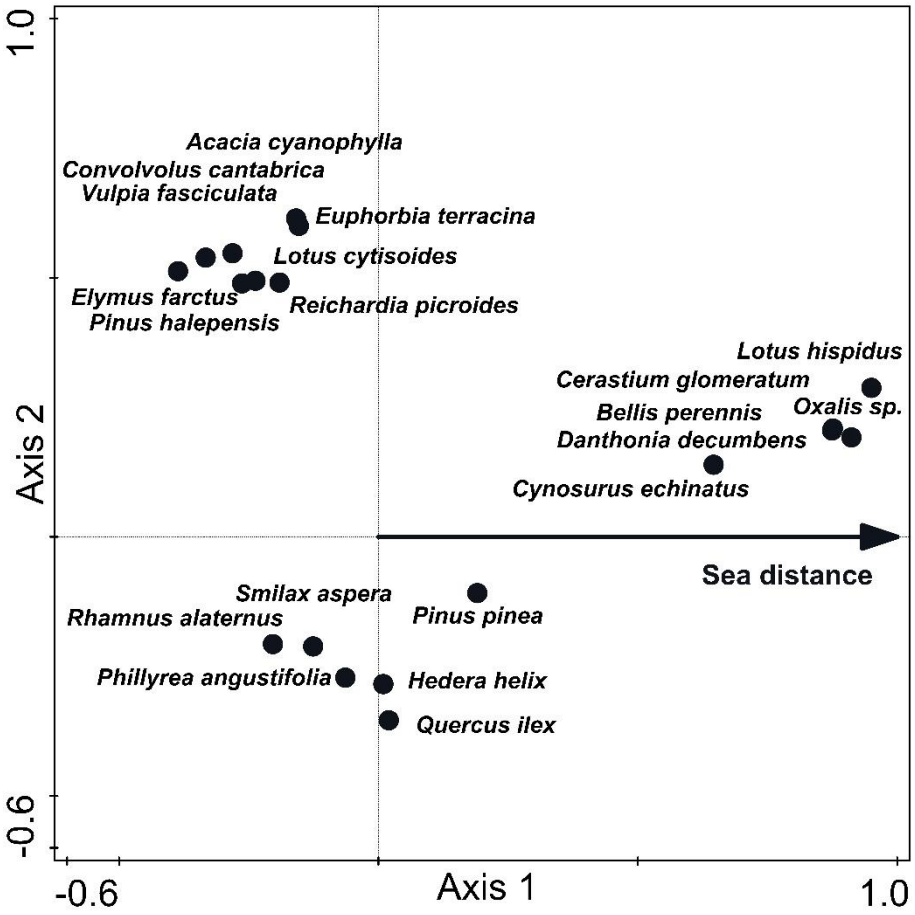

Figure 5 Hybrid constrained CCA diagram. Axis 1 captured 3.2% of the variance (p = 0.001). The first 20 best fitting species in the ordination spaces are shown.

Hybrid constrained CCAs with canopy cover of *Pinus halepensis* and *P. pinea* (Figure 6) revealed the significant effect of pine cover on the understorey. In both CCAs, lower canopy cover was associated with herbaceous and shrub species of natural dunal succession, whereas higher canopy

cover was associated with generalist and alien species. Hybrid constrained CCA with *P. pinaster* did not produce significant results and is therefore not shown.

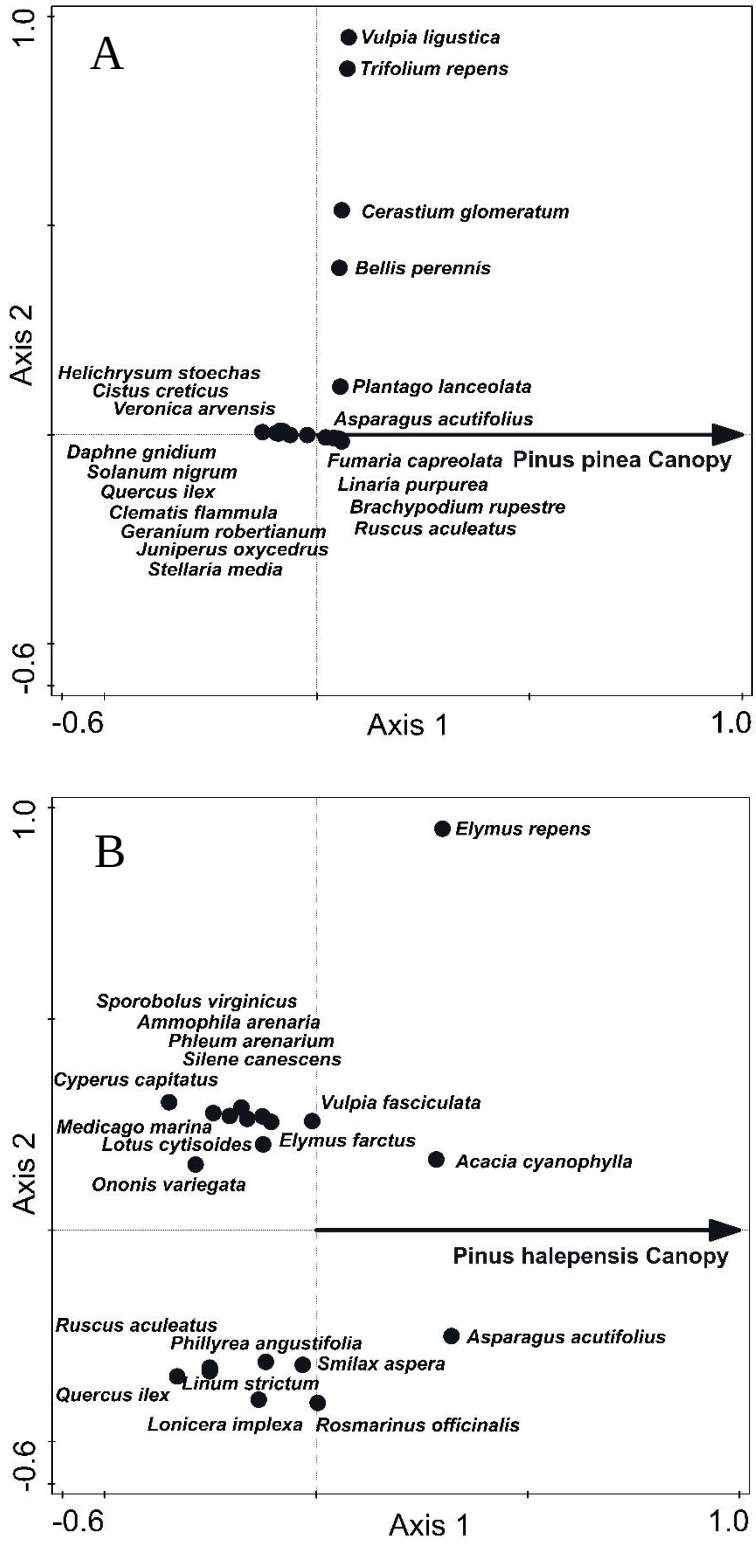

Figure 6 Hybrid constrained CCA diagrams. (A) Pinus pinea canopy-constrained. (B) P. halepensis canopy-constrained. Axis 1 captured 1.5% of the variance (p = 0.013) and 3.1% (p = 0.001), respectively. The first 20 best fitting species in the ordination spaces are shown.

GAMs on pine species revealed that the probability of occurrence of *P. pinea* and *P. halepensis* respectively, responded significantly to distance ($p < 0.001$). The curve trends (Figure 7) showed that *P. pinea* showed its greatest probability of occurrence after the first 1000 m, continuing for the rest of the sea-inland gradient. On the other hand, *P. halepensis* had the highest probability of occurrence in the first 1000 m from the coast and then disappeared. The *P. pinaster* curve is not shown in Figure 7 because it was not significant.

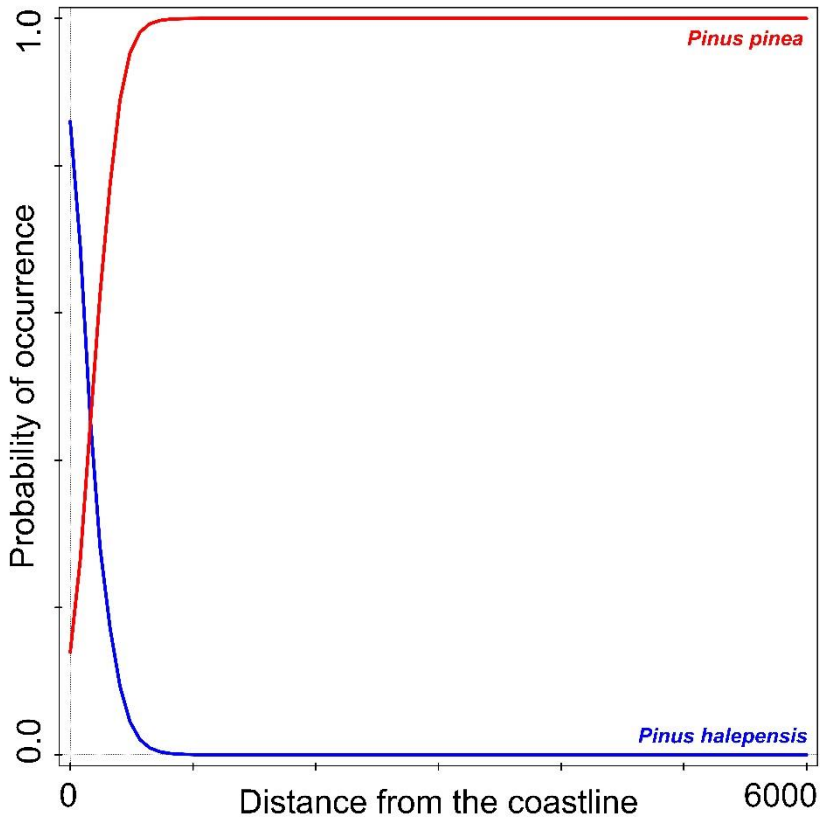

Figure 7 Species-response curves (GAMs; 2.0 df) of pine species with respect to sea distance (m). Pinus pinea (R2 29.9; F 4.8) and P. halepensis (R2 31.4; F 5.2) were significant ($p < 0.001$).

GAMs revealed 14 species that responded significantly to distance from the coastline based on hybrid CCA (Figure 8; Appendix B, Table S25). Along the sea-inland gradient, dune species sensu strictu, such as *Lotus cytisoides*, showed maximum probability of occurrence close to the sea, while innerdune species (e.g. *Phillyrea angustifolia*, *Quercus ilex* ssp. *ilex* and *Brachypodium sylvaticum* ssp. *sylvaticum*) showed maximum response at intermediate distances, and species not linked to dune vegetation succession, such as *Brachypodium rupestre*, were found at high distances.

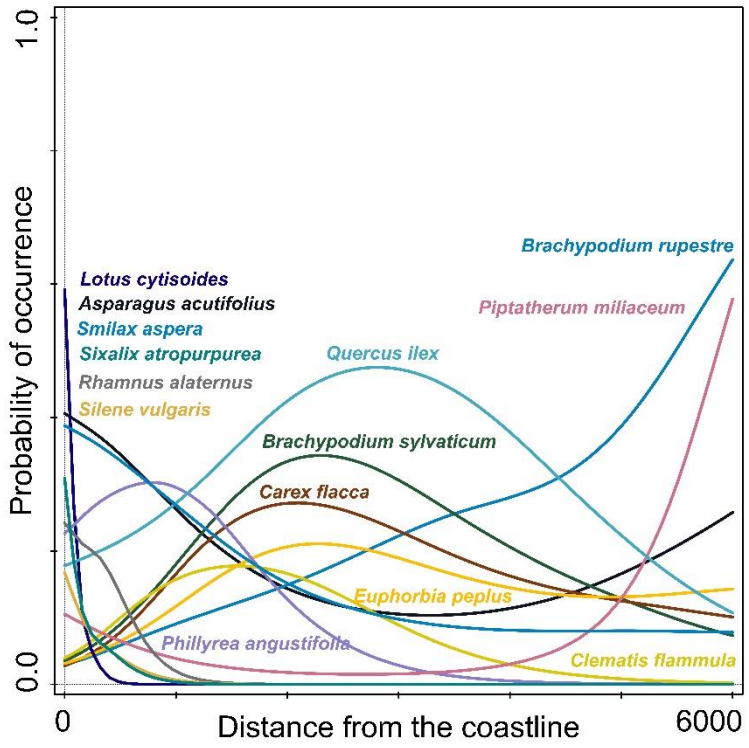

Figure 8 Species-response curves (GAMs; 2.0 df) of species with more than 10 occurrences in the dataset with respect to sea distance (m). Only significant models are shown.

GAMs to test understorey species trends in relation to *P. pinea* or *P. halepensis* canopy cover showed four species in both cases that responded significantly to distance to the coastline (Appendix B, Table S26). *Sixalix atropurpurea* and *Quercus ilex* ssp. *ilex* showed a higher probability of occurrence at lower canopy cover of *P. pinea*, whereas species such as *Brachypodium sylvaticum* ssp. *sylvaticum* and *B. rupestre* preferred higher canopy cover of *P. pinea* (Figure 9a). For *P. halepensis* a common trend of focal dune species was found (*Lotus cytisoides*, *Sporobolus virginicus*), showing higher occurrence at lower canopy cover of the pine and then sharply decreasing, whereas *Piptatherum miliaceum*, which is not a focal dune species, showed a different trend (Figure 9b).

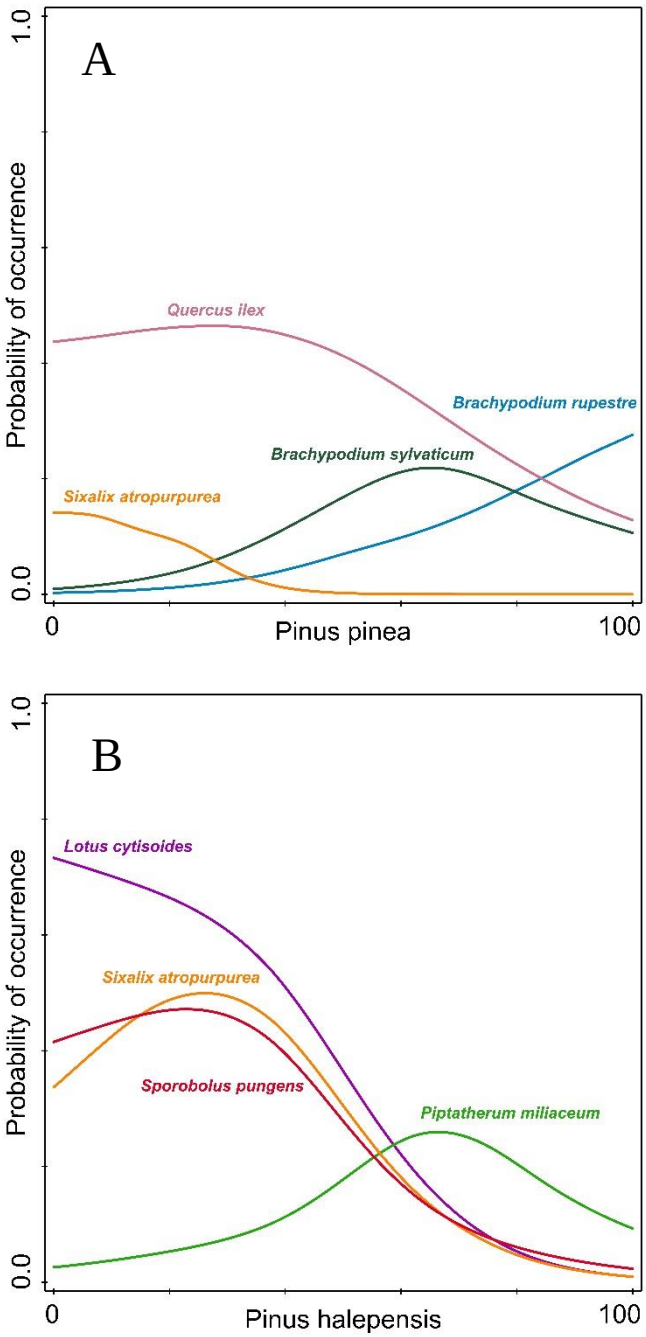

Figure 9 Species-response curves (GAMs; 2.0 df) with respect to canopy cover (%) of Pinus pinea (A) and P. halepensis (B) on species with more than 10 occurrences in plots. Only significant models are shown.

4. Discussion

The community pattern revealed vegetation associated with different pine forest types converging into a single cluster with little difference in plant species composition. This suggests that the different coastal pine forest types are not characterized by floristically and ecologically distinct understoreys. Pine stands therefore do not differentiate a specific species pool of plants having special affinities for a pine overstorey type. Vascular plant species can generally colonize plantation forests regardless of canopy species when habitat characteristics are appropriate (Carnus et al., 2006). Since all the pine forest stands studied shared substantially the same coastal dune environment, known to be a very selective habitat for plants (Maun, 2009), the lack of floristic differentiation between them can therefore be explained by their relatively similar environmental conditions (Frelich et al., 2003). Moreover, other authors have considered environmental conditions to be more important drivers of understorey community composition than dominant tree species (Piwczyński et al., 2016). In the same perspective, species composition may be highly variable and change substantially in response to environmental change in each pine forest type. Stands of different pine types, planted across the sea-inland gradient where natural vegetation zonation ranges from pioneer communities of embryonic dunes to oak forests, have been found to host a variety of species, mainly distributed according to this gradient and often adapted to coastal environments near the sea shore (psammophilous species) (Acosta et al., 2003).

Although MRPP and NMDS suggested low distinctiveness at community level, T statistics indicated that different pine forest stands showed some differences at species level. IndVal supported this thesis, highlighting that a small pool of species was more likely to occur in one pine forest type than another. Notably, 20 species showed significant affinity for Pinus halepensis stands, 11 of which were focal for coastal dunal habitats (Biondi et al., 2009; Biondi and Blasi, 2015) and in some cases were strictly psammophilous. Among these, *Sporobolus virginicus* and *Elymus farctus* ssp. *farctus*, typical of embryonic Mediterranean dunes (Acosta et al., 2007; Biondi et al., 2009; Biondi et al., 2012), showed the highest indicator values for P. halepensis forest. On the other hand, in line with Biondi et al. (2009) and Biondi and Blasi (2015), forest species were linked to *P. pinea* stands, where *Brachypodium sylvaticum* ssp. *sylvaticum* was the species with the highest indicator value. This may be related to the fact that *P. halepensis* stands were often planted closer to the sea, whereas *P. pinea* stands were planted relatively far from the coastline and therefore had a higher probability of occurrence along most of the sea-inland gradient. In fact, *P. pinea* has been reported to have a wide range of distribution in coastal dune habitats, mostly growing on fixed dunes and in areas with deep water table and relatively low salinity (Antonellini and Mollema, 2010; Angiolini et al., 2013). The

spatial location of these two pine forest types, positioned slightly differently with respect to each other and extending from the foredunes to the innermost dunes (paleodunes), reflects the different ecology of the pine species. Indeed, P. halepensis is more pioneer, well adapted to drought (Mauri et al., 2016) and able to spread by seed from plantations into adjacent natural plant communities (Higgins and Richardson, 1998 ; Lavi et al., 2005), occasionally also colonizing the inner part of the foredunes. Thus, the indicator species for *P. halepensis* forest type were largely very specialized psammophilous plants that grow exclusively on embryonic dunes, tolerating salt spray, drought and unstable substrates (Acosta et al., 2000). According to Maestre and Cortina (2004), late-successional plant species are rarely observed in *P. halepensis* plantations, even after several decades. On the contrary, the species pool of P. pinea stands consisted of forest undergrowth species, including nemoral and basically sciaphilous plants of evergreen oak forest, typical of the natural vegetation of inner dunes and dune slack transition zones (Acosta et al., 2003). In fact, also Brockerhoff et al. (2003) found that some, especially older, pine stands showed affinities with nearby native forests, allowing establishment of many native forest understorey species. The lack of pattern for *P. pinaster* forest type in our study, was probably due to the low number of plots available for this type (N = 8). In addition, we could not suggest any specific ecological factors influencing the lack of ecological and floristic distinctiveness with respect to the other pine forest types.

When we tested the distance to coastline as a driving force of coastal pine forests, our results indicated that it had a significant role for pine understorey assemblages, according to its key function for the composition of natural sand dune communities (see Forey et al., 2008; Kim and Yu, 2009; Angiolini et al., 2013; Ruocco et al., 2014). Like on non-forested dunes, understorey pine forest species followed the natural vegetation zonation along this gradient, with dune species, such as *Elymus farctus* ssp. *farctus* and *Lotus cytisoides*, occurring closer to sea, and forest species of backdune evergreen oak forests, such as *Quercus ilex* ssp. *ilex*, *Brachypodium sylvaticum* ssp. *sylvaticum* and *Carex flacca*, in the intermediate stands (Acosta et al., 2000). On the contrary, ruderal and generalist species such as *Brachypodium rupestre*, *Piptatherum miliaceum*, *Bellis perennis* and *Cynosurus echinatus* had the highest probability of occurrence in more inland stands. We observed a relationship between understorey assemblages and the sea-inland gradient with most of the focal species related to the natural dune zonation. Thus, these planted forests partially maintain the previous assemblage of coastal vegetation, consonant with their inclusion in EU priority habitat 2270.

Pine canopy is an important factor in Mediterranean forests, affecting plant species assemblages, seedling establishment and soil fauna (McIntosh et al., 2016; Granados et al., 2016; Selvi et al., 2016; Bonari et al., 2017). Our data confirmed that *P. halepensis* and *P. pinea* canopies significantly affected understorey plant communities, particularly at high coverage. Thus, plant assemblages were affected similarly by the tree canopy, regardless the pine species. Typical dunal herbaceous and shrub species, such as *Lotus cytisoides*, *Ononis variegata, Sporobolus virginicus*, *Clematis flammula* and *Juniperus oxycedrus* ssp. *macrocarpa*, which are heliophilous, often growing on oligotrophic soils, had higher probability of occurrence with lower pine cover. Interestingly, not only the herbaceous layer was affected by pine cover, as already shown by Madrigal-Gonzaléz et al. (2010), but also shrub and tree species, including holm oak (*Quercus ilex* ssp. *ilex*), which had lowest probability of occurrence under high canopy cover. As suggested by Lemenih et al. (2004), plantations with denser canopies host lower density and richness of woody species in the understorey. On the other hands, Brockerhoff et al., 2003; Brockerhoff et al., 2008 also found that understorey vegetation beneath the canopy of pine plantations may show a successional trend towards increasing dominance of native shade-tolerant species that are typical of natural forest understoreys. In this study, beneath higher pine canopy, the only shade-tolerant forest species found were *Brachypodium sylvaticum* ssp. *sylvaticum* and *Asparagus acutifolius*, while we detected an increase in the alien invasive *Acacia cyanophylla* and in generalist species, such as *Fumaria capreolata* ssp. *capreolata, Brachypodium rupestre*, *Elymus repens* ssp. *repens*, *Piptatherum miliaceum* and *Bellis perennis* showing a negative effect of canopy covers on natural dune vegetation.

5. Conclusions

We studied Italian coastal pine forest stands, analysing the influence of different pine species, sea-inland gradient and pine canopy cover on their understoreys at community and species level. At community level, our results support the lack of differentiation among different forest types. However, at species level minor differences in understorey assemblage were found. These differences seem mainly related to pine ecology and sea-inland gradient than to pine specific forest types. In fact, coastal dune vegetation was relatively preserved below pine canopy, so our result support the idea that coastal pine forests may maintain the “valuable” Mediterranean coastal biodiversity pool. This could be related to the fact that all the pine species were introduced inside their original range of distribution, as well as to the long time established planting. Moreover, our results provide useful

insights into the role of Mediterranean coastal pinewoods and afforestations. Thus, species-specific management strategies are not necessary for different pine forests, and a long-sighted management approach should take into account other factors based on the understorey species assemblages linked to the coastal dune zonation and canopy cover. Finally, our results, suggest that pine stands should no longer be considered a potential threat to biodiversity. Mediterranean pinewoods do not reflect an "ecological desert" but can host many dune focal species and a mosaic of natural habitats in their understoreys, also providing ecosystem services that should be not overlooked.

Chapter 3

Concordance between plant species, oribatid mites and soil in a Mediterranean stone pine forest

Keywords:

Coastal areas; Community composition; Congruence; Oribatid mites; *Pinus pinea*; Vegetation structure

Abstract

Biological interactions between above-ground and below-ground organisms are not clearly defined among communities with regard to compositional patterns. The study investigates the concordance of species assemblages between vascular plants and oribatid mites and soil chemical properties with special attention to the role of vegetation structure, i.e. tree, shrub and herbaceous cover, for biological components. Data were collected in a Mediterranean coastal Nature Reserve using sampling design based on random selection of plots with cover of stone pine (*Pinus pinea* L.) exceeding 15%. Agreement of distribution patterns was verified by Spearman's rank correlation coefficient applied to pairs of matrices of plot scores by principal component analysis (plants, mites and soil) and the Mantel test. The feasible role of vegetation cover on plant and mite assemblages was tested by redundancy analysis (RDA). Significant correlations were found for biological assemblages, indicating congruent plant–mite compositional patterns. On the other hand, the hypothesis of concordance between biological communities and soil was rejected. Moreover, RDA showed that vegetation cover was a driver of both plant and oribatid mite assemblages. In particular, herbaceous cover proved to be a good proxy for the two biological communities investigated, with different taxa linked to forest clearings and to areas with denser tree cover. Our results indicate that soil features were not of primary importance for below-ground and above-ground community assemblages in the study area. In the light of our findings and ongoing threats in coastal areas, we recommend that management measures be directed at maintenance of diversified vegetation structure, which may ensure above-ground and below-ground biodiversity with diverse biological community assemblages.

1. Introduction

Understanding of biotic interactions between above-ground and below-ground soil communities is an important target (Hooper et al., 2000), since ecologists regard species interactions as major processes controlling species composition and their richness. The surge of interest in soil biological diversity springs largely from recognition that organisms sharing this physical environment regulate major ecosystem processes and from the likelihood that feedbacks between above-ground and below-ground communities have a key role in governing ecosystem function (Wardle, 2002). Plants are the key component for life: they entertain a series of exchanges with the surrounding world, including soil fauna, and influence below-ground environmental conditions by driving changes in litter state, pH and moisture (Wardle et al., 2005; Bezemer et al., 2006). Among micro-arthropods in the soil system, oribatid mites (Arachnida) in the organic horizons are one of the richest groups. They are actively involved in decomposition of organic matter, circulation of nutrients, and formation and maintenance of soil structure (Bardgett and Wardle, 2010). Their abundance, species distribution and community structure depend on their reactions to biotic and abiotic environmental conditions, which show spatial variation with latitude and also at fine-scale level within sites, although deterministic and stochastic processes may both play a role (Lindo and Winchester, 2009; Nielsen et al., 2012; Minor, 2011; Caruso et al., 2012). They are sensitive to habitat evolution and to several types of disturbance, including pollution, land use, management and fire (Henig-Sever et al., 2001; Lindo and Visser, 2004; Migliorini et al., 2005a, b). The intricate relationships between these edaphic invertebrates and their ecological niches in the soil matrix, the fact that many of them live a rather sedentary life, and the stability of community composition at a specific site (Maaß et al., 2014) provide good starting points for bioindication of changes in soil properties (Behan-Pelletier, 1999; Feketeová et al., 2015; Tsiafouli et al., 2015).

Concordance among different taxonomic groups can derive from similar but independent responses by these groups to the main environmental gradients (Paavola et al., 2003). Evidence of cross-taxon concordance across spatial and ecological gradients is increasing, and it can form a basis for reliable use of surrogates to monitor trends in biodiversity (Rooney and Azeria, 2015). Many studies have dealt with congruence, analysing animals, lower plants or fungi interacting with vascular plants (e.g. Chiarucci et al., 2007; Maccherini et al., 2009; Landi et al., 2015), while others relate above- and below-ground communities (e.g. Mitchell et al., 2010; Santi et al., 2010; Rooney and Azeria, 2015). Patterns of oribatid mite diversity have been studied in pine plantations composed of Pinus radiata

(Minor, 2011), whereas to our knowledge congruence between plants, oribatid mites and soil parameters has never been analysed in a stone pine forest. Moreover, in wooded areas, it is generally assumed that vegetation cover can be used as a proxy for light, a major environmental variable for plant communities (González-Alday et al., 2009) and soil organisms (Rutigliano et al., 2004; Iovieno et al., 2010).

Considering the strong interactions of vascular plant and oribatid mite communities with the soil system, we determined to verify: (1) the hypothesis of concordance between biological communities (vascular plants and oribatid mites) and the chemical features of soil; (2) the role of vegetation cover as a driver of vascular plant and oribatid mite communities in a wooded protected area in the Mediterranean basin. The main aim of our research was to gain insights into interactions between the two biotic communities and soil features to use as a basis for forest management in protected areas.

2. Materials and methods

2.1. Study area

The study area was the "Nature Reserve of Duna Feniglia" on the Tyrrhenian coast of southern Tuscany (Italy) (UTM 32T 684506.73 E; 4699193.80 N). The Feniglia Dune was declared a protected area with State Nature Reserve status in 1971 and acquired Special Protection Area status in 1979 to protect the lagoon of Orbetello. The protected area is a sandy strip (maximum altitude 14 m) connecting the promontory of Mt. Argentario with the coast. It is largely vegetated with stone pines (*Pinus pinea*) managed for conservation and not subject to cutting. The area experienced human-induced degradation (between 1700 and 1900) and subsequent rehabilitation, including dune consolidation and sowing of stone pines in the early 1900s (see Landi et al., 2012; Angiolini et al., 2013).

Stone pine stands have been a frequent planting choice in the Mediterranean area over the last century, characterizing large stretches of coast in the western part of Italy and becoming a widespread semi-natural ecosystem. These areas are currently considered a priority habitat for conservation in Europe

under the Habitats Directive 92/43/CEE (European Commission, 2003). Although the autochthony of this species in Italy is still unclear, these forests, traditionally cultivated for timber and pine nuts, have the important function of stabilizing sand dunes and defending back-dune crops from sea spray (Antonellini and Mollema, 2010; Cutini et al., 2013).

The geology of the area features quaternary deposits of carbonate-rich marine sandy and sandy–silty sediments forming coastal and inner dunes. According to Barazzuoli et al. (1993), climate is sub-arid Mediterranean with mild winters and very hot dry summers. The mean annual precipitation is approximately 677 mm with a Mediterranean rainfall regime (Regione Toscana, 2014).

2.2. Field sampling design and laboratory procedures

The study focused on wooded dunes with *Pinus pinea* belonging to priority habitat 2270*. The area of Feniglia Dune Nature Reserve with stone pine forest was selected from ortho-photographs (scale 1:5000), interpreted visually on a video screen with the aid of geographic information system. Twenty plots (10 × 10 m) in the inner dunes were randomly allocated and sampled. When tree cover proved to be less than 15%, another plot was chosen. The study did not involve any experimental manipulations or disturbance of naturally developed relationships. During field surveys (conducted in spring), all vascular plant species occurring in each plot were recorded and their individual covers estimated (vertical projection of plants) as percentages between 0 and 100. A field estimate of cover was also recorded for each layer (tree, shrub and grass layer). Plant species nomenclature was according to Conti et al. (2005).

At the same time as the vegetation survey, litter was removed at the centre of each plot in order to sample the surface layer of the soil profile (top 20 cm). A cubic core (20 × 20 × 20 cm) was sampled to study soil. Three cubic cores (10 × 10 × 10 cm repetitions) were also obtained nearby to study oribatid mites. The cores were sampled as close as possible to each other. Oribatid mites were subsequently extracted with a modified Berlese–Tullgren apparatus and preserved in 75% ethyl alcohol. Adult individuals were identified and counted at species level using a stereoscopic microscope. The species were listed according to Weigmann (2006). Soil samples were taken using decontaminated polypropylene tools and kept in hermetically sealed decontaminated polypropylene

containers. In order to preserve soil integrity, the samples were immediately transported under gel packs and refrigerated (4 °C) on arrival at the laboratory. In the laboratory, soil samples were air-dried and sieved using a 2-mm mesh sieve. The soil fraction < 2 mm (fine-earth fraction) was homogenized by quartering and pulverization and analysed to determine the following properties: pH, salinity (as NaCl; g/kg), carbonate content (as CaCO3; g/kg), soil organic matter (SOM; g/kg), total nitrogen content (TN; g/kg), field capacity (FC; g/kg) and density (D; kg/L). Measurements of soil properties were according to the USDA/NRCS (2004) methods manual. Total nitrogen was determined by direct total flash combustion using an element analyser with thermal conductivity detector (CHN/O 200, Perkin Elmer). Recoveries and reproducibility were checked by analysing procedural blanks and standard reference materials (SRM1944 and Tibet Soil); the reproducibility test indicated a coefficient of variation of > 95%, and the analytical limit of quantification (LOQ) was 0.01% for TN. All laboratory analyses were performed in triplicate.

2.3. Data analysis

Four data sets were obtained: (1) percentage cover for each plant species (plant community composition); (2) oribatid mite species mean abundance (mite community composition); (3) physical and chemical soil properties; and (4) percentage cover of each vegetation layer, i.e. tree, shrub and herbaceous layer (vegetation structure). The plant data set was subject to generalized log transformation [log generalized = log(x + x min) − log(x min)], because there were values less than 1.0 in the matrix (McCune and Grace 2002; Peck 2010). With regard to mites, the mean abundance of the three repetitions in each plot was calculated and log(x + 1) transformation was used. Because soil data were expressed in incompatible units, it was reduced to a common scale (interval 0–1) by subtracting the minimum observed for each variable and dividing by the range, namely applying the method of ranging proposed by Sneath and Sokal (1973). To prevent excessive noise in the data matrix from obscuring certain data features, plant species with cover less than or equal 0.1 occurring only once (29 species) and oribatid mite singletons (37 species) were excluded from the analysis. In initial analysis with all the data, it was confirmed that these two categories do not improve the analyses.

The concordance among plant communities, mite communities and soil properties was tested using two techniques with the intention of determining whether the results remained consistent under

different procedures. In order to decide whether it was better to use ordination methods based on a model of linear species response to the underlying environmental gradient or weighted averaging ordination methods, corresponding to a model of unimodal species response (Lepš and Šmilauer, 2003), explorative detrended correspondence analysis (DCA) was performed. Since the first axis gradient was always < 4.00 SD, three principal component analyses (PCA) were performed. Coordinates (scores) of plots in each PCA (mites, plants and soil) were used to create pairs of matrices, tested with Spearman's rank correlation coefficient (SRCC) to evaluate the concordance in distribution patterns between plant community, mite community and soil properties. A Mantel test (MT) was also performed to assess concordance of community-level patterns between plants, mites and soil properties from the same set of sample units. MT evaluates the null hypothesis of no relationship between two dissimilarity (distance) or similarity matrices. Finally, two separate redundancy analyses (RDAs) were performed with mites and plants, using species and tree, shrub and herbaceous cover data as explanatory variables. The significance of the first ordination axis and all canonical axes together was tested by a Monte Carlo randomization method, using 999 permutations.

DCA, PCA and MT analyses were performed using the software package PcOrd 6.0 (McCune and Mefford, 2011). SRCC was performed using the STATISTICA v. 7.1 software package (StatSoft Italia Srl., 2005). RDAs were calculated using CANOCO v. 5.03 (ter Braak and Šmilauer, 2012).

3. Results

3.1. Biological components

A total of 95 vascular plants were recorded in 20 plots (for details, Appendix C, Table S27) with an average number of species per plot of 13.7 ± 7.4 (mean ± SD). The highest number of species per plot was 32, the lowest 3. *Pinus pinea* was the only species present in all plots, followed by *Pistacia lentiscus* (17 out of 20) and *Inula conyzae* (12 out of 20 plots). Mean tree cover was 54.65% (range 15–98%) with dominant species such as *Pinus pinea*, *Quercus ilex*, *Q. suber*, *Fraxinus angustifolia* subsp. *oxycarpa* and *Ulmus minor*. Mean shrub cover was 33.15% (range 0–100%) with dominant species such as *Phillyrea angustifolia*, *Pistacia lentiscus* and *Juniperus oxycedrus* subsp. *macrocarpa*. Mean herbaceous cover was 14.65% (range 0.5–85%) with frequent species such as

Anagallis arvensis, *Carex distachya*, *Catapodium rigidum* and *Brachypodium rupestre*. Vines such as *Hedera helix* and *Tamus communis* were also present.

A total of 100 oribatid mite species were recorded in 20 plots (for details, Appendix C, Table S28) with a mean number of species per plot of 20.3 ± 9.09 (mean ± SD). The highest number of species per plot was 40, the lowest 4. The species with the greatest number of individuals was *Sphaerochthonius splendidus*. The highest number of individuals per plot was 508, the lowest 16. The average number of individuals per plot (density) was 181 ± 144.01 per cubic core. Species occurring more frequently were *Microppia minus* (17 out of 20) and *Chamobates borealis* (15 out of 20 plots).

3.2. Soil properties

Table 8 shows the main statistical indices of physical and chemical properties measured in soil samples (for details, Appendix C, Table S29).

Table 8 Main statistical indices (Mean, SD, Max and Min) of physical and chemical properties of soil samples: pH, salinity (as NaCl; g/kg), carbonate content (as CaCO3; g/kg), soil organic matter (SOM; g/kg), total nitrogen content (TN; g/kg), field capacity (FC; g/kg) and density (D; kg/L)

	pH	**NaCl**	**$CaCO_3$**	**SOM**	**TN**	**FC**	**D**
Mean	6.3	0.6	115.6	61.4	2.1	413.4	1.9
DS	0.96	1.01	75.85	46.31	2.23	115.72	0.17
Max	7.86	4.33	290	215.47	8.10	703.94	2.16
Min	4.36	0.08	32	13.62	0.001	250.67	1.54

The analytical data indicated low-to-moderate variability in most properties (except a few anomalous values of pH). Although pH values were highly variable, most soils were moderately to slightly acid or neutral. NaCl content was distinctive of non-saline soils. Higher NaCl concentrations were measured in some slightly to moderately saline soils collected closer to coastal dune zone. In line with the geolithological characteristics of the parent rock (carbonate-rich sandy and sandy–silty sediments), soils were moderate-to-high calcareous. Assuming that SOM typically contains 58% carbon, the soils of Feniglia Dune had high to very high organic carbon content (Costantini, 2006) as well as medium to high nitrogen content. The high levels of field capacity (FC) were typical of clay

loam to clay soils rich in organic matter. Density (D) values decreased with increasing SOM and confirmed that soils were rich in organic substances.

3.3. Community concordance between plant community, mite community and soil properties

Variance explained by the first PCA axis was 21.97% for plant data, 24.04% for oribatid mite data and 49.14% for soil properties. The correlation between scores of the first PCA axes of plants, oribatid mites and soil features only showed significant correspondence between the data of plant and mite communities ($r = 0.55$; $p < 0.05$). The results of MT agreed with those of PCA, only showing a significant correlation between plant and mite communities ($r = 0.428$; $p < 0.01$).

All RDA axes with data constrained by vegetation layer cover were significant for plant and mite community data ($p < 0.01$), and the total explained variation was 26.5 and 30.8%, respectively. The biplots of RDA in Figure 9 and Tables 10 and 11 show the relationships between vegetation covers (vectors) and biological data (arrows). In the biplot for plants (Figure 9a), the main correlations were: axis 1 was positively associated with herbaceous cover and *Brachypodium rupestre*; axis 2 was negatively associated with shrub cover and *Pistacia lentiscus*; axis 3 was negatively associated with tree cover and *P. pinea*. In the biplot for oribatid mites (Figure 9b), the main correlations were: axis 1 was positively associated with herbaceous cover and *Scheloribates laevigatus*; axis 2 was positively associated with tree cover and *Metabelbella interlamellaris*; Axis 3 was negatively related to shrub cover and *Scheloribates initialis*.

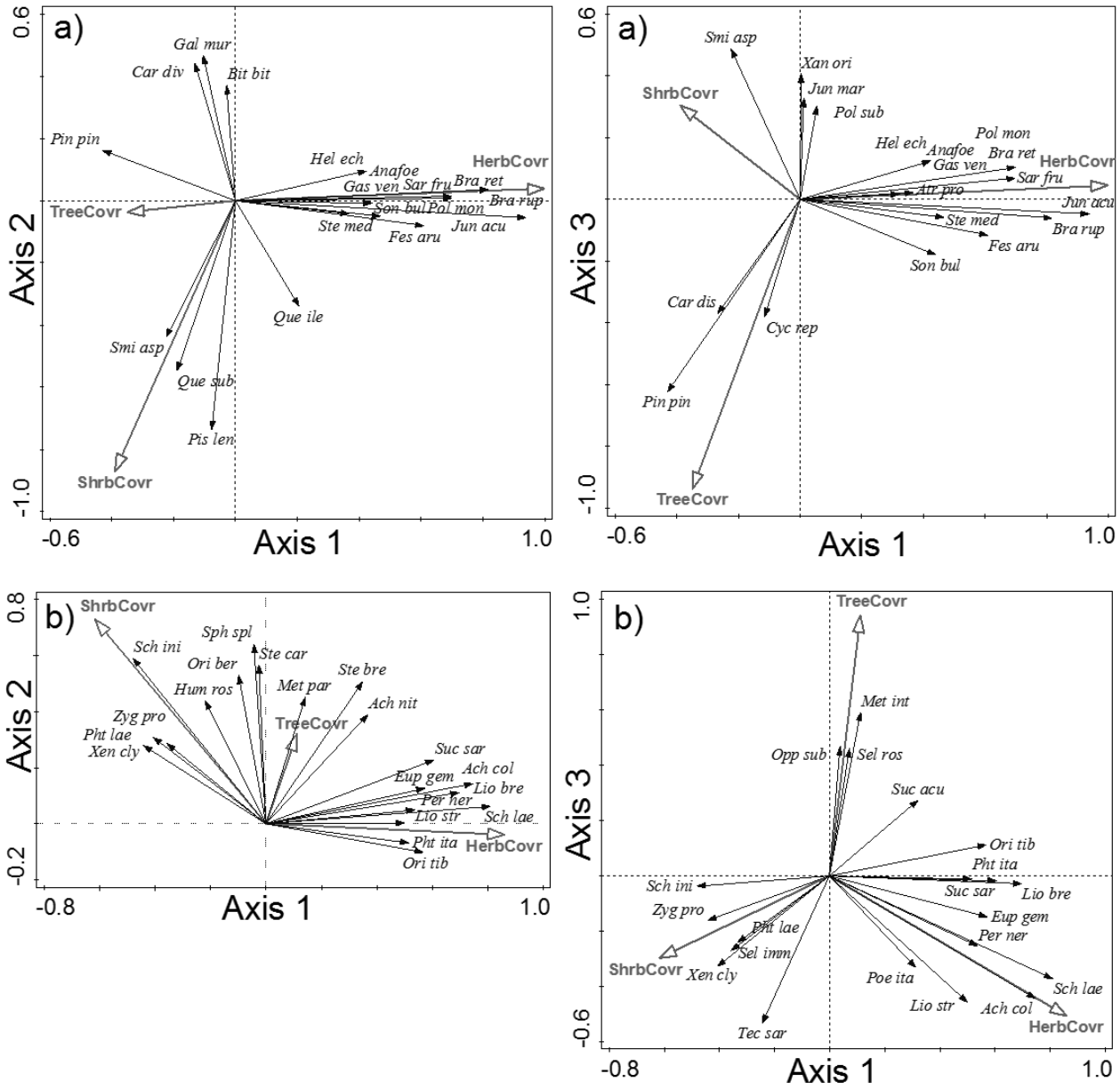

Figure 9 Constrained ordinations (RDA) are reported showing the 20 species of best fit: a) plants; b) mites. Abbreviations of environmental variables: TreeCovr = Tree cover; ShrbCovr = Shrub cover; HerbCovr = Herbaceous cover. Abbreviations for plants and mites can be found in Table S27–S29.

Table 10 Correlation matrix of constrained ordination (RDA) of plants and cover

	Ax1	**Ax2**	**Ax3**
Variance (%)	(14.17)	(9.65)	(2.71)
Trees cover	-0.3181	-0.0305	-0.5216
Shrubs cover	-0.3541	-0.7093	0.1690
Herbaceous cover	0.9087	0.0319	0.0252

Table 11 Correlation matrix of constrained ordination (RDA) of mites and cover.

	Ax1	**Ax2**	**Ax3**
Variance (%)	(14.55)	(9.69)	(6.54)
Tree cover	0.1033	0.2320	0.7508
Shrub cover	-0.5669	0.5273	-0.2376
Herbaceous cover	0.7913	-0.0281	-0.4047

4. Discussion

Vegetation composition, variation in soil properties and the spatial configuration of habitat patches shape below-ground communities, affecting composition and species diversity patterns of soil fauna (Widenfalk et al., 2015), which generally prove sensitive to habitat evolution, although sensitivity varies considerably between groups and single species (Maraun and Scheu, 2000). In line with this concept, our results suggest a concordant distribution pattern between plant and mite communities in a Mediterranean stone pine forest, with significant correlation in ordinations indicating parallel variation in species composition among taxonomic groups (Santi et al., 2010; Rooney and Azeria, 2015). These findings were consistent across all analyses (PCA, MT and RDA). Vegetation composition is affected directly and indirectly by a wide range of drivers, such as climate, land management and soil chemistry, which will also influence soil fauna. Moreover, in some cases vegetation composition can summarize these drivers and prove more related to oribatid mites than to soil chemistry. Mitchell et al. (2010) recorded similar results for soil microbial communities. The common distribution patterns we observed between communities of vascular plants and mites can also be due to factors not investigated here, such as the physical space created by roots (less compact texture), which creates a more suitable habitat for mite communities. This below-ground network can affect soil microclimate, maintaining temperatures constant, providing nourishment (mites can be predators of root pests; Wissuwa et al., 2012) and modifying rhizodeposition, as well as the quality and quantity of litter (Maharning et al., 2009). Conversely, the influence of soil mesofauna on vascular plants is reflected by patterns resulting from feedback involved in community dynamics (Klironomos, 2002; De Deyn et al., 2003). It is worth recalling that: (1) cross-taxon congruence patterns are highly complex; (2) correlations cannot be causal in nature; (3) correlation of above-ground and below-ground diversity does not necessarily imply mechanistic linkages, but is a first step

in assessing whether such linkages exist; (4) above-ground organisms and their ecological mechanisms are better known than below-ground ones (Hooper et al., 2000; Santi et al., 2010).

The present study did not find support for the hypothesis of concordance between biological communities and soil chemical properties, although plants and mites were concordant and shared the soil matrix. This may at first seem surprising, as certain studies have shown that high variability of soil chemistry as well as environmental and/or human disturbance might determine evident gradients that reflect similar patterns in soil and oribatid mites (Migliorini et al., 2005b; Keith et al., 2012) or vascular plants (Bernard-Verdier et al., 2012; Angiolini et al., 2013). The lack of relationships could also be due to: (1) scale, which is important to understand above-/below-ground interactions; (2) the uniform geolithological background consisting essentially of sand; and (3) homogeneous land use. In line with Nielsen et al. (2012), we can state that soils support highly diverse communities due to their great spatial complexity at very fine scales and the small size of soil organisms. Oribatid mites have no specialized dispersal stages, and dispersal is very limited; thus, they may only travel distances of a few centimetres per day. In any case, the appropriate scale to avoid misleading spatial autocorrelation sampling is still unclear for managed and natural environments alike (Minor, 2011). Furthermore, it is relatively common not to find any correlation or only weak ones. Gradients in soil systems may change at plot scale due to high spatial variability in abiotic factors. In the stone pine forest of the study area, only soil pH was highly variable, mainly due to the influence of pine needles and soil mineralogical features, specifically carbonate content, but it was not significantly linked to biotic composition. This agrees with previous findings that soil pH does not directly affect oribatid mite densities and composition, but may control other physicochemical and biotic factors not investigated in this study (e.g. other saprophagous groups or macro-decomposers such as earthworms). Oribatid mites seem to tolerate much variation in soil chemical and physical parameters, and they do not seem directly affected by factors such as soil pH. In fact, scrolling through the literature, we see, for example, that proventricular glands have been described as multifunctional organs (Alberti and Coons, 1999; Pigino et al., 2006) devoted to the production of digestive enzymes, as well as participation in light reception and pH regulation. However, in other studies conducted in pine forests, pH seemed to influence the occurrence of mites (Minor, 2011) and vascular plants (Angiolini et al., 2013), directly and in a major way. Our results may therefore be affected by the scale of sampling, which is known to affect cross-taxon studies (Hess et al., 2006), also because at finer scales, species distribution is probably less related to soil parameters than at regional scales (Palmer, 1990) and at finer scales, biotic site parameters may be more important than soil conditions

(Bruelheide and Udelhoven, 2005). This circumstance may be related to the fact that local mite communities in soil are known to be sensitive to fine-scale environmental gradients, each related to the physical structure of the underground parts of plants or litter quality (Gergócs et al., 2015), even if stochastic factors can dominate oribatid mite assemblages at different scales, as suggested by Caruso et al. (2012). These authors also attribute this source of stochasticity to different environmental conditions typical of certain areas, making it necessary to interpret local soil communities as islands subject to extinction and immigration (Maaß et al., 2014).

The role of vegetation cover, tested as a key factor driving changes in biological communities, proved to be a driver that influences vascular plant and mite community compositions, in line with their congruent distribution patterns, probably related to similar auto-ecology of the species or their spatial covariation. The main driver of plant and mite communities among vegetation cover was herbaceous layer cover. Correspondence between species of communities in relation to vegetation cover was clearly revealed by direct ordinations linked to stone pine canopy heterogeneity. Under conditions of high tree cover, more homogeneous plant data were recorded. On the other hand, in clearings with high herbaceous cover, there was more plant variability, as found in other semi-arid Mediterranean areas (González-Alday et al., 2009; Madrigal-Gonzalez et al., 2010). Interestingly, some commonalities and strong relationships between certain plant and mite species and vegetation cover were identified. Many studies have demonstrated that the distribution of oribatid mites is not random but aggregates according to trophic resources and soil moisture (Usher et al., 1982). For example, the decline in population density during the dry months is less severe in soils with the dense vegetation cover; daily and seasonal variations in temperature are less extreme than in open sites, and supply of organic matter provides food resources and trophic niches for oribatid mite communities throughout the year (Migliorini et al., 2002). In our study, mite communities showed a certain number of euryoecious species related to meadows and open areas (Magowski and Niedbala, 2013). *Scheloribates laevigatus*, constantly present in grasslands at these latitudes, was associated with herbaceous cover dominated by *Brachypodium rupestre*, a species of meso-thermophilic herbaceous edges of pine forests and woods in general, and other graminoids. Relationships between tree cover, *Pinus pinea* and *Metabelbella interlamellaris*, seemed to confirm the ecological traits of the latter species, typical of Mediterranean thermophilous forests. Similarly, *Scheloribates initialis*, constantly collected in transition habitats, was related to a shrub species, *Pistacia lentiscus*; both are typical in the same biogeographical district.

5. Conclusions

The community similarity approach, comparing patterns of concordance, is an appropriate protection measure, although no single path of conservation planning can be sufficient for all environmental situations (Su et al., 2004). The link between above- and below-ground diversity in natural environments is certainly convoluted and depends on the taxa studied and the scale used (Hooper et al., 2000; Ettema and Wardle, 2002; Wardle et al., 2004; Mitchell et al., 2010). Our efforts provide insights on a small part of this intricate system. Indeed, even with awareness of the complexity of these types of interactions, interrelationships, factor combinations and their underlying mechanisms, the webs are very hard to study and predict. Although further research is needed to test our results over a wider range of vegetation and soil types, our study demonstrates a clear relationship between vascular plant and oribatid mite communities in a Mediterranean stone pine forest. Vegetation cover can be considered a driver of both mite and plant communities. The data suggest that maintenance of diversified vegetation cover may ensure various biological community assemblages and higher biodiversity in stone pine forest stands. Thus, these results offer some perspectives for practical application in biodiversity conservation management and planning in Mediterranean stone pine forests and possibly for priority habitats in general. With due precaution, they could open the way to joint management considerations for these two biological communities, improving awareness of protection of two (above- and below-ground) communities in one, but also awareness that any wrong management of one of these two communities may also have a negative impact on the other.

Chapter 4

Focal plant species and soil factors in Mediterranean coastal dunes: an undisclosed liaison?

Keywords:

Chemical properties; Community composition; Gradients; Habitat; Models; Edaphic niches

Abstract

Understanding the response of plant species to soil factors on coastal sand dunes is critical for effective conservation of coastal habitats in the Mediterranean basin. Our main objectives were to investigate: (i) the main soil factors driving species composition in a Mediterranean coastal dune environment; (ii) the ecological requirements of focal plant species with respect to single soil factors; (iii) whether the focal species of a given macrohabitat (including EU habitats) have similar edaphic needs. We identified 108 plots with three macrohabitats as strata (embryo dunes; mobile dunes; fixed dunes) by random stratified sampling design along the Tyrrhenian coast of central Italy in areas with a high degree of biodiversity and naturalness. Vegetation and soil data were collected in the plots.

Canonical Correspondence Analysis (CCA) confirmed that soil had a main role in driving focal dune species composition as found in other Mediterranean areas and indicated that three factors (field capacity, pH and $CaCO_3$) sufficiently explain patterns of plant species. An inverse relation between field capacity, which proves to be the most decisive feature for differences in species ecological requirements between macrohabitats, and pH was observed. Generalized Additive Models (GAMs) showed that: (i) the focal species of fixed dunes have a higher probability of occurrence and response curves that overlap at high field capacity and TOC values and at low pH, showing an opposite trend with respect to the species of embryonic and mixed dunes; (ii) species of mixed dunes have a probability of occurrence linked to different values of $CaCO_3$, with *Ammophila arenaria* showing its optimum at high $CaCO_3$ values. Thus our results sustain the hypothesis that dune focal species, diagnostic of different macrohabitat, have different ecological responses with respect to soil factors. Moreover, species within the same habitat can have different ecological responses due to species competition. Data about edaphic requirements of sand dune species and modelling of their ecological

responses suggests that focal dune species can be bio-indicators of soil conditions and provide useful indications for conservation, monitoring and restoration of Mediterranean coastal habitats.

Keywords: chemical properties; community composition; gradients; habitat; models; edaphic niches.

Abbreviations: $CaCO_3$ calcium carbonate; EC electrical conductivity; ED embryo dunes; FC field capacity; FD fixed dunes; MD mobile dunes; SOM soil organic matter; TOC total organic carbon; TC total carbon; TN total nitrogen.

1. Introduction

Coastal dune ecosystems are characterized by a gradient of natural stress and disturbance along sea-inland transects, leading to compressed zonation of plant communities (Acosta et al., 2003; Forey et al., 2008; Carboni et al., 2011). This is a unique habitat assemblage with high ecological diversity in terms of environmental variability and highly specialized flora, rarely shared with other terrestrial ecosystems (Heslenfeld et al., 2008; Acosta et al., 2009; Ciccarelli, 2014). These ecosystems also provide services such as coastal protection from erosion, groundwater storage, water purification and carbon storage (French, 2001; Drius et al., 2016). The Habitats Directive 92/43/EEC, the most effective legal instrument concerning biodiversity and conservation of nature at European level (Wätzold and Schwerdtner, 2005; Gigante et al., 2016), describes the importance of the environmental heterogeneity of coastal sand dunes in Europe. In Annex I of this Directive about 20 coastal dune habitats, most of which occur also in Italy, are listed (European Commission, 2007; Heslenfeld et al., 2008; Biondi et al., 2009).

The many human-related disturbance factors affecting coastal ecosystems include erosion, agriculture, urban development, spread of alien species and tourist pressure (Ciccarelli et al., 2012; Ciccarelli, 2014; Malavasi et al., 2014; Santoro et al., 2012). Human pressure is causing physical and chemical changes in coastal dune soils that lead to a decrease or even local extinction of species (Buffa et al., 2005), as well as fragmentation, profound modification and in some cases destruction of typical dune plant communities (Kutiel et al., 1999; Nielsen et al., 2011). This is particularly dangerous because these ecosystems are mainly composed of specialized niche species with narrow ecological ranges and special eco-physiological adaptations (Acosta et al., 2003; Ercole et al., 2007;

Ciccarelli, 2015). In fact, dune species are closely related to abiotic factors that change rapidly along the sea-inland gradient: salty sea spray, wind, erosion, substrate instability and drought decrease, while soil nutrient concentrations and soil compaction increase (Maun, 2009; Forey et al., 2009; Ciccarelli, 2015). Recent studies on Mediterranean coastal dunes highlighted local soil aspects as the main factors driving variability of dune vegetation (Fenu et al. 2013; Ciccarelli, 2014; Ruocco et al., 2014), in contrast to ocean dunes, where wind-related parameters seem to control vegetation zonation (Wilson and Sikes, 1999; Hernández-Cordero et al., 2015). The ecological range of dune species with respect to single soil chemical factors is important for identifying differential sensibilities of these species to soil components and their changes (Novoa et al., 2014). The effects of nitrogen deposition, for example, are not likely to be similar for species with different nitrogen requirements. Species requirements are therefore relevant in the context of ongoing environmental changes in order to predict how habitat modifications may alter or even destroy specific species-rich vegetation in dune ecosystems in decades to come. Acquiring this data becomes crucial in the Mediterranean Basin where coastal systems are considered highly threatened (Lemauviel and Rozé, 2003; De Luca et al., 2011; Feola et al., 2011).

Although many researchers have focused on the relationships between plant communities and soil factors in coastal dunes (Ihm et al., 2007; Kim and Yu, 2009; Brunbjerg et al., 2012), also in Mediterranean areas (Molina et al., 2003; Angiolini et al. 2013, Ruocco et al., 2014), and on functional traits at species level to explore plant adaptation to environmental factors (Bermúdez and Retuerto, 2014; Ciccarelli et al., 2009, 2010; Gratani and Bonito, 2009; Spanò et al., 2013), to the best of our knowledge no studies have modelled single dune plant species responses to edaphic gradients, a common approach in the study of species niches, whether fundamental or realized.

The aim of the present study was to define the soil factors determining focal plant species composition in Mediterranean coastal dunes. We used ordination and predictive models of dune species responses to soil gradients; these are powerful tools for answering questions in vegetation ecology and conservation biology (Guisan and Thuiller, 2005). Focal species are taxa that characterize different vegetation types and indicate habitat conditions where they are found, also being particularly responsive to a range of threats and habitat modifications (Chiarucci et al., 2008; Santoro et al., 2012). This is why focal dune species were the main subject of our analysis of plant-soil relationships. Our hypotheses were that focal dune plants have different reactions to soil factors and different soil factor requirements (realized niches), and that these result in changes according to niche segregation among different habitat types. More specifically, we attempt to answer the following questions: (i) What are the main soil factors driving species composition in Mediterranean coastal dune environments? (ii)

What are the ecological requirements of dune focal species with regard to soil factors? (iii) Do focal species of a given macrohabitat have similar edaphic needs?

2. Materials and Methods

2.1. Study area

The study was performed on the Tyrrhenian coast of central Italy, where there are areas with a high degree of biodiversity and naturalness (Vagge and Biondi, 1999; Ciccarelli et al., 2014) and plant communities associated with 10 habitat types *sensu* Habitats Directive 92/43/EEC. These areas have been considered threatened or vulnerable (Viciani et al., 2007) and are suitable for studying relationships between sand dune species and soil factors in the Mediterranean basin.

Four sites were investigated: Sterpaia (42°57'N, 10°37'E), Duna "Canale San Leopoldo" (42°44'N, 10°56'E), Duna Feniglia (42°25'N, 11°15'E) and Duna di Burano (42°23'N, 11°22'E) (Figure 10).

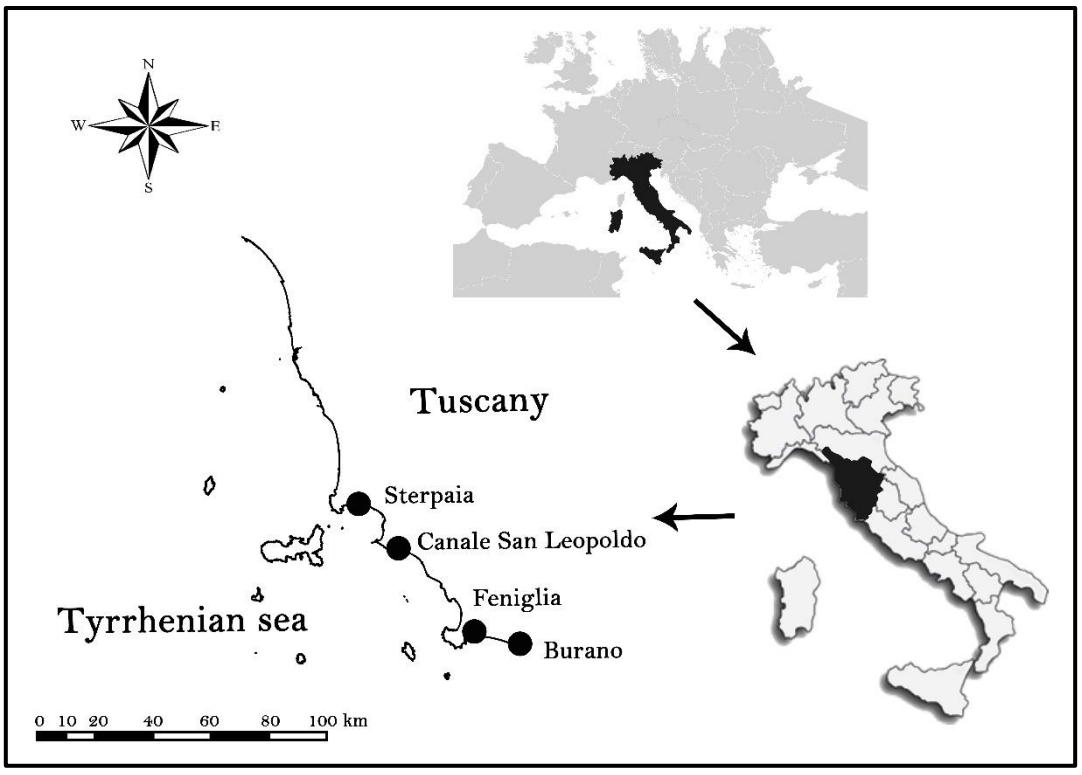

Figure 10 Locations of the study sites in the Tyrrhenian coast of central Italy. Black points represent the four sites investigated.

These sites have similar climatic and environmental characteristics. Climate is Mediterranean semiarid with dry summer and rainfall peaks concentrated in autumn and winter (Barazzuoli et al., 1993). Geologically, the sites are mainly composed of Holocene sand consisting of quartzitic material containing calcium carbonate, chlorides and iron compounds (Mancini, 1953; Bertini et al., 1968). The dune ecosystems of these sites have different conservation status (Landi et al., 2012) and host natural vegetation attributed to the following herbaceous and shrubby habitats of Community interest (European Union Habitats directive, see Biondi et al., 2009, 2012; Viciani et al., 2014) along a coastal-inland gradient: 1210 – Annual vegetation of drift lines; 2110 – Embryonic shifting dunes; 2120 – Shifting dunes along the shoreline with *Ammophila arenaria*; 2210 – *Crucianellion maritimae* fixed beach dunes; 2230 – *Malcomietalia* dune grasslands; 2240 – *Brachypodietalia* dune grasslands with annuals; 2250 – Coastal dunes with *Juniperus* spp.; 2260 – *Cisto-Lavanduletalia* dune sclerophyllous scrub.

2.2. Sampling design and field surveys

Ortho-photographs were interpreted visually on a video screen with the aid of Geographic Information System in order to obtain the most representative possible sample of dune vegetation. The following three macrohabitats were selected in the four sites: (i) embryo dunes and partially vegetated upper beach (1210, 2110; Embryo Dunes: ED); (ii) mobile white and transition dunes with a dense herbaceous layer (2120, 2210, 2230; Mobile Dunes: MD); (iii) fixed dunes with a shrub layer (2240, 2250, 2260; Fixed Dunes: FD). To obtain uniformly distributed plots along the coastline (a total of 6 km for each site), three sectors of equal length (2 km each) were mapped perpendicular to the coastline and a random selection was performed in each sector using the three macrohabitat types as strata. Vegetation data was collected by random stratified sampling. We sampled 108 plots (3 plots × 3 sectors × 3 habitat types × 4 sites) measuring 10 × 10 m located in the field by GPS (mean error < 5 m). In each plot, all vascular plant species were recorded as presence/absence and a soil sample (20 × 20 × 20 cm) was collected from the middle of the plot.

Plant species nomenclature was in accordance to the Checklist of Italian Vascular Flora (Conti et al., 2005) for native species and to the The Plant List (2013) for exotic species. As focal species for dune ecosystems we considered the diagnostic or characteristic species indicated in the Interpretation

Manual of Directive 92/43/EEC (Habitats Directive) for coastal dune habitats (Biondi et al., 2009; 2012). In fact, the Habitats Directive lists a series of diagnostic species for habitats of conservation interest, species that play a major role in determining the structure and functioning of these systems. These species may directly or indirectly control the availability of resources for other species (see also Santoro et al., 2012; Malavasi et al., 2014; Del Vecchio et al., 2015). Among them, typical species *sensu* Evans and Arvela (2011) or main diagnostic species (see Bazzichetto et al., 2016) may act as synthetic indicators of the conservation status of the entire habitat.

2.3. Soil analysis

After sieving (fine-earth fraction < 2 mm), laboratory analysis was performed in triplicate on representative sub-samples to determine nine variables: calcium carbonate ($CaCO_3$), electrical conductivity (EC), field capacity (moisture retained in the soil after drainage of excess water by force of gravity; FC), salinity (as NaCl), soil organic matter (SOM), soil pH, total organic carbon (TOC), total carbon (TC) and total nitrogen (TN). Analysis of $CaCO_3$, EC, FC, NaCl, SOM, pH and TOC was conducted according to the USDA/NRCS (2004) methods manual, while TC and TN were determined (in triplicate) by direct total flash combustion using an element analyzer with a thermal conductivity detector (Perkin Elmer, mod. CHN/O 200).

2.4. Data analysis

Using a matrix of 108 plots × 37 species with all focal species included except singletons (those occurring in only one relevé), Detrended Correspondence Analysis (DCA) was applied to species data, detrending by segments and downweighting rare species to measure the length of the longest axis. This suggested that unimodal ordination methods would be appropriate for the data (4.1 SD; Lepš and Šmilauer 2003). Since inclusion of a strongly intercorrelated group of variables in the ordination may yield unreliable results (ter Braak and Šmilauer, 2012), the soil variables were first tested for correlation by the Pearson correlation coefficient. SOM and NaCl showed a high correlation with TOC and EC, respectively ($r > 0.9$), and were therefore excluded from the analysis. Since the soil values were expressed in incompatible units, they were reduced to a common scale by the ranging method of Sneath and Sokal (1973) that allows simultaneous adjustment of the magnitude and variability of the descriptors. A matrix of 108 plots × 7 soil variables ($CaCO_3$, EC, FC, pH, TOC, TC

and TN) was then produced. Canonical Correspondence Analysis (CCA; ter Braak and Šmilauer, 2012) was used to determine whether soil factors significantly drive dune species composition, testing the significance of the first, second and all canonical axes ($p \leq 0.0001$).To assess the relative importance of each soil factor, the most parsimonious model was fitted using a stepwise algorithm, adding the explanatory variables to the model to select the soil factors that best explained variations in the dataset, until the variables were not significant ($p > 0.05$). The randomised Monte Carlo test (9999 permutations) and Bonferroni correction for multiple comparisons were applied (ter Braak and Šmilauer, 2012).

To recognise the ecological requirements of focal species with respect to soil factors, we used non-parametric Generalised Additive Models (GAMs; Hastie and Tibshirani, 1990). These are empirical models, connecting field observations with predictive environmental variables, based on statistically or theoretically obtained species-response surfaces (Guisan and Zimmermann, 2000). They support a non-Gaussian error distribution and a non-linear relationship between response and predictor variables (Austin and Meyers, 1996). In our study the response data was the presence-absence of species, so binomial distribution was assumed with a quasi distribution approach and a log-link function that allow modelling of non-normally distributed over-dispersed count data. To simplify the additive models in this study, we restricted each species-predictor response to a curve using a maximum of three degrees of freedom (df). Higher polynomials tend to reveal biologically unfeasible response shapes that are more difficult to interpret (Austin et al., 1990; Bio et al., 1998). The optimum degree of freedom for each species was selected by the Akaike Information Criterion (AIC) (Akaike 1973; Sakamoto et al. 1986) that identifies the most parsimonious model from a set of candidate models (Burnham and Anderson 2002). Since variation explained by GAMs is determined by deviance (Zuur et al., 2009), where explained data variability is the percentage of deviance explained, we used explained deviance expressed as follows, as a measure of model fit: 100 × (deviance of a null model/residual deviance of an actual model)/deviance of a null model. Response models were only shown for focal species highly significant ($p < 0.01$).

CCA and GAMs were performed using CANOCO package version 5.04 (ter Braak and Šmilauer, 2012) and correlations by Statistica 7.1 (StatSoft Inc., 2005).

3. Results

The species list consisted of 139 vascular plants, 37 of which (about 26.6%) are focal for dune habitats and 8 are the main diagnostic species considering the total flora recorded (Appendix D, Table S30).

Table 12 Macrohabitats (ED, MD and FD) identified in the coastal sand dunes indicated by name, EU Habitat type code (Directive 92/43/EEC) and focal species. The main diagnostic species are in bold.

Macrohabitat name	EU Habitat type Code	Focal species
ED: Embryo dunes and partially vegetated upper beach	1210 - 2110	***Anthemis maritima, Cakile maritima* ssp. *maritima***, *Calystegia soldanella, Centaurea sphaerocephala,* ***Chamaesyce peplis*, *Cyperus capitatus*, *Echinophora spinosa*, *Elymus farctus* ssp. *farctus, Elymus athericus,*** *Eryngium maritimum, Euphorbia paralias,* ***Matthiola sinuata*, *M. tricuspidata, Medicago marina,*** *Otanthus maritimus ssp. maritimus,* ***Salsola tragus*, *Sporobolus virginicus*.**
MD: Mobile white and transition dunes with a dense herbaceous layer	2120 - 2210 2230	***Ammophila arenaria* ssp. *australis***, *Anthemis maritima,* ***Cyperus capitatus, Crucianella maritima,*** *Cutandia maritima,* ***Echinophora spinosa,*** *Eryngium maritimum, Lagurus ovatus, Matthiola tricuspidata,* ***Malcolmia ramosissima,*** *Medicago littoralis,* ***M. marina, Ononis variegata, Otanthus maritimus* ssp. *maritimus, Pancratium maritimum, Pseudorlaya pumila, Silene canescens, Stachys maritima, Vulpia fasciculata.***
FD: Fixed dunes with a shrub layer	2240 - 2250 2260	*Asparagus acutifolius, Helichrysum stoechas, Lagurus ovatus,* ***Juniperus oxycedrus ssp. macrocarpa***, ***J. phoenicea ssp. phoenicea***, *Phillyrea angustifolia, Rhamnus alaternus ssp. alaternus, Rubia peregrina, Smilax aspera.*

A summary of the soil factor characteristics in each of the three macrohabitats (Table 13) showed that the highest values of pH, EC and $CaCO_3$ occurred in embryo dunes, while the highest FC, TC, TN and TOC occurred in fixed dunes. In line with its transitional position, mobile dune macrohabitats had soil factor values generally intermediate between the other two habitats (embryo dunes and fixed dunes), but also the lowest EC, TC and TN values.

Table 13 Descriptive statistics of soil factors including mean and standard deviation (SD) calculated separately for three macrohabitat (ED, MD and FD) plot datasets.

Macrohabitats	**ED**: Embryo dunes and partially vegetated upper beach		**MD**: Mobile white and transition dunes with dense herbaceous layer		**FD**: Fixed dunes with shrub layer	
Soil factors	Mean	SD	Mean	SD	Mean	SD
$CaCO_3$ (g/kg)	218.61	92.89	204.31	96.82	188.33	85.58
EC (mS/cm)	234.01	340.06	88.74	31.73	134.45	66.56
FC (g/kg)	205.91	84.04	224.99	95.30	254.52	103.53
pH	9.08	0.55	8.97	0.58	8.22	0.58
TC (g/kg)	34.26	15.05	32.92	14.59	35.93	22.91
TN (g/kg)	0.90	1.29	0.82	1.53	1.30	2.85
TOC (g/kg)	1.30	1.05	1.64	1.53	2.69	2.71

3.1. Soil factors and focal species composition

The CCA with dune focal species and soil chemical factors along the first three axes explained a relatively low percentage of variance in species composition (6.8%, 5.9% and 2.4%, respectively) but all were highly significant ($p < 0.001$; Figure 11).

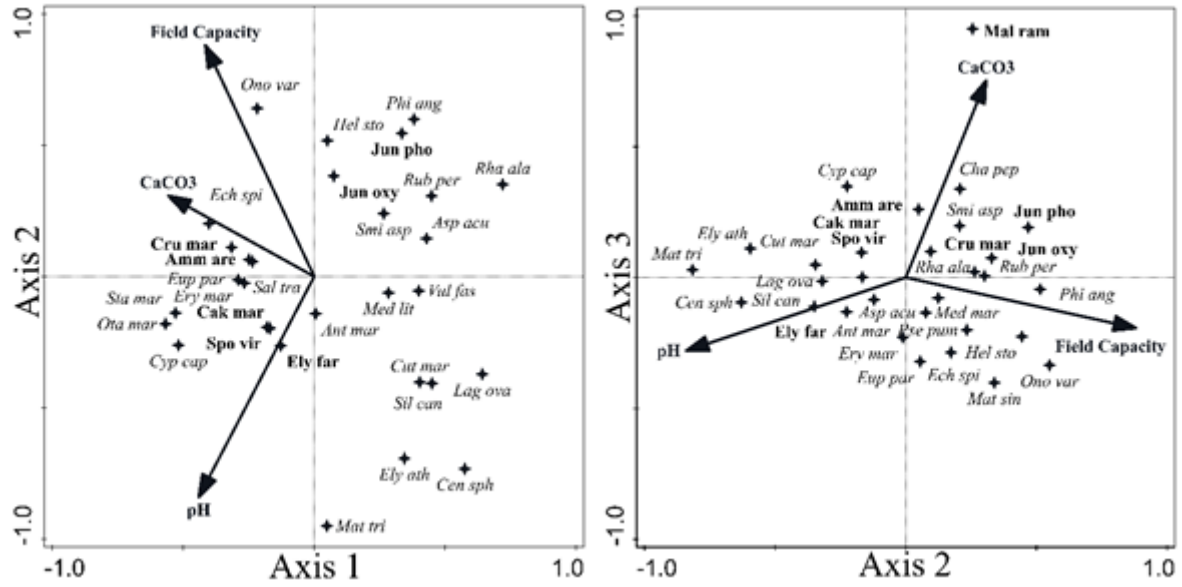

Figure 11 Biplot graphs with species distributed on the basis of Canonical Correspondence Analysis (CCA). The arrows match the significant soil variables (Field Capacity; CaCO3 and pH). The axes are in units of standard deviation for the scale. Only the species with the highest fit range are reported in the graphs; the main focal species are in bold. The abbreviations of genus and species in the graphs are the first three letters as shown below in bold type: Ammophila arenaria ssp. australis; Anthemis maritima; Asparagus acutifolius; Cakile maritima; Calystegia soldanella; Chamaesyce peplis; Centaurea sphaerocephala; Crucianella maritima ssp. maritima; Cutandia maritima; Cyperus capitatus; Echinophora spinosa; Elymus athericus; Elymus farctus ssp. farctus;

Eryngium maritimum; Euphorbia paralias; Helichrysum stoechas; Juniperus oxycedrus ssp. macrocarpa; Juniperus phoenicea ssp. phoenicea; Lagurus ovatus; Malcolmia ramosissima; Matthiola tricuspidata; Medicago littoralis; Medicago marina; Ononis variegata; Otanthus maritimus ssp. maritimus; Pancratium maritimum; Phillyrea angustifolia; Pseudorlaya pumila; Rhamnus alaternus ssp. alaternus; Rubia peregrina; Salsola tragus; Silene canescens; Smilax aspera; Sporobolus virginicus; Stachys maritima; Vulpia fasciculata.

The Monte Carlo Permutation Test indicated that only three significant ($p = 0.0007$) explanatory variables (FC, CaCO3 and pH) were included in the CCA model and together they explained 82.8% of the total variance (17.9%). FC and pH were the main predictors, explaining 31.3% and 30.3% of the total variance in the dataset, followed by CaCO3 that also accounted for a high percentage of variance (21.2%), while EC, TC, TN and TOC were not significant, although TOC was significant at $p < 0.05$ when tested independently (simple effect). The first axis was negatively correlated with CaCO3 ($r = – 0.55$; $p < 0.01$), pH ($r = – 0.49$; $p < 0.01$) and FC ($r = – 0.38$; $p < 0.01$). The second axis was positively correlated with FC ($r = 0.86$; $p < 0.01$) and CaCO3 ($r = 0.27$; $p < 0.01$) and negatively with pH ($r = – 0.84$; $p < 0.01$). The third axis was positively correlated with CaCO3 ($r = 0.78$; $p < 0.01$) and negatively with pH ($r = – 0.30$; $p < 0.01$). The CCA diagram showed a high spread of species in biplot space. The focal species of embryo dune macrohabitat were situated at high pH (*Elymus farctus*, *Sporobolus virginicus*, *Cakile maritima*) or low FC (*Elymus athericus*, *Cutandia maritima* and *Silene canescens*), while those of fixed dune macrohabitat (e.g. *Juniperus* spp., *Helichrysum stoechas*) showed the opposite trend. Focal species of mobile dune macrohabitat (e.g. Ammophila arenaria, Crucianella maritima and Malcolmia ramosissima) were situated at the highest $CaCO_3$ values.

3.2. Responses of focal plant species to soil factors

The responses of focal plant species to the soil predictors, fitted by GAMs and significant at $p < 0.01$ level, are shown in Table 14; the species response curves are in Figure 12.

Table 14 Results of Generalized Additive Models (GAMs) for 18 statistically significant (p < 0.01) focal species (main focal species in bold). The macrohabitat (ED, MD and FD) of each species is indicated. D2 = Percentage of explained deviance; AIC = Akaike information criterion.

Macro habitat	**Predictor variables**	**$CaCO_3$**		**EC**		**FC**		**pH**		**TC**		**TOC**	
	Response	D^2	**AIC**	D^2	**AIC**	D^2	**AIC**	D^2	**AIC**	D^2	**AIC**	D^2	**AIC**
ED	***Cakile maritima* ssp. *maritima***							7.0	140.80				
ED	***Elymus farctus* ssp. *farctus***							9.4	120.28				
ED	*Euphorbia paralias*					16.7	90.18					8.9	94.88
ED	*Salsola tragus*											7.8	133.46
ED	***Sporobolus virginicus***							13.6	132.75				
ED/MD	*Anthemis maritima*	5.5	142.59										
ED/MD	*Echinophora spinosa*	20.6	85.92	26.4	87.09	20.9	85.18					10.8	94.02
ED/MD	*Eryngium maritimum*					13.0	99.16			12.2	99.62		
MD	***Ammophila arenaria* ssp. *australis***	7.9	131.73					11.9	130.25				
MD	*Medicago marina*			9.4	125.37								
MD	*Pancratium maritimum*					9.2	138.66						

MD	*Vulpia fasciculata*	9.6	110.91			10.2	112.06						
MD/FD	*Lagurus ovatus*			16.1	94.50	31.6	78.03			10.8	98.11	12.0	97.88
FD	*Asparagus acutifolius*	12.3	100.76	11.2	101.74								
FD	*Helichrysum stoechas*					35.5	85.40	9.1	113.65				
FD	***Juniperus oxycedrus* ssp. *macrocarpa***					11.2	129.98	16.0	123.06				
FD	*Phillyrea angustifolia*					11.6	100.35						
FD	*Smilax aspera*							15.6	124.73			7.9	133.72

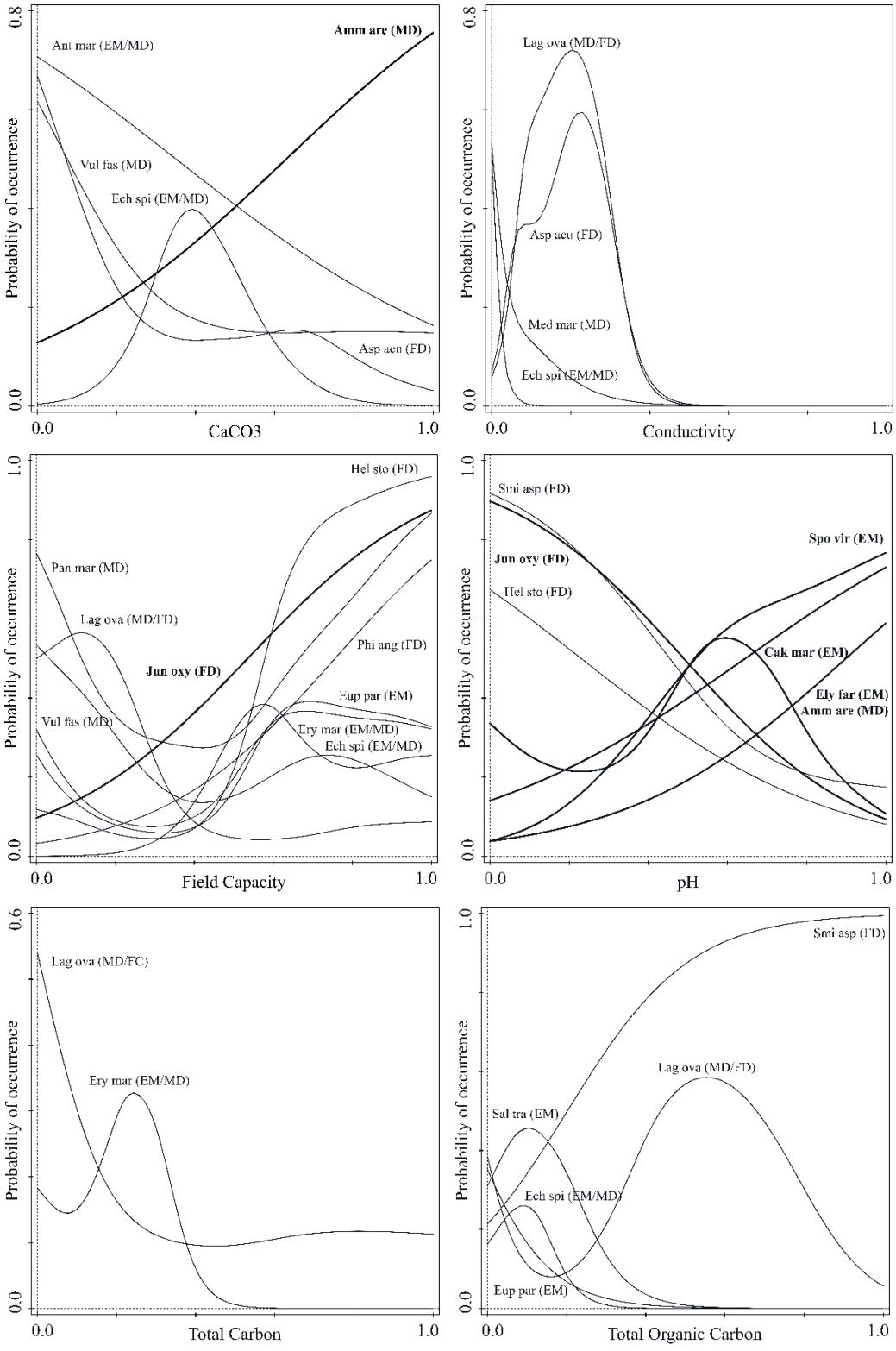

Figure 12 Response curves (probability of occurrence) of focal plant species significantly related ($p < 0.01$) to soil factors (see Table 14); main focal species in bold. For abbreviations of species names, see the legend of Figure 11. The macrohabitat/s (ED, MD or FD) for which each species is diagnostic is/are indicated in brackets.

The deviance-based test (F and p-values) showed that most of the fitted GAMs were significantly better than the null models for FC, pH and, secondarily, for $CaCO_3$. The GAM performed along the FC gradient explained a variable percentage of species occurrence from 35.5% for *Helichrysum stoechas* to 9.2% for *Pancratium maritimum* with nine significant species. Among the main diagnostic species, only *Juniperus oxycedrus* ssp. *macrocarpa* showed a significant association with this factor and its response was monotonic increasing. Responses to soil pH were significant for seven focal species (deviance explained 7-16%). All main focal species were significantly associated with this factor that distinguished *Sporobolus virginicus*, *Elymus farctus* and *Cakile maritima* with bimodal or monotonic increasing response curves, from *J. oxycedrus* ssp. *macrocarpa* with monotonic decreasing response and from *Ammophila arenaria* with a bimodal trend and an optimum response at average pH. With regard to CaCO3, five species, all of mobile dune macrohabitats, showed significant responses, with *A. arenaria* displaying linear monotonic increasing response and Anthemis maritima the opposite response. For the other soil factors (TOC, EC and TC) we obtained five, four and two significant species responses, respectively, none of which involved main focal species. However, some showed a high explained deviance, for example *Echinophora spinosa* and *Lagurus ovatus* for EC (26.4% and 16.1%, respectively), *L. ovatus* for TOC (12%) and *Eryngium maritimum* for TC (12.2%).

Analysis of the response curves distinguished groups of focal species for each macrohabitat with similar environmental requirements and distribution patterns along gradients (Figure 12). Species on embryo dunes showed the highest probability of occurrence at high pH (i.e. *S. virginicus*, *C. maritima* and *E. farctus*) or overlapping along the FC gradient (*E. spinosa*, *E. maritimum*, *Euphorbia paralias*) and TOC gradient (*Salsola tragus* and *E. spinosa*) at medium-high and low values, respectively. Species on mobile dunes demonstrated the highest probability of occurrence at low FC (*L. ovatus* and *Vulpia fasciculata*) or low EC values (*Medicago marina* and *E. spinosa*). On the other hand, species on fixed dunes (i.e. *H. stoechas*, *J. oxycedrus* ssp. *macrocarpa*, *Smilax aspera* and *Phillyrea angustifolia*) responded most to low pH and high FC or showed a relatively narrow range of occurrence with curves overlapping at low EC values (*L. ovatus*, *Asparagus acutifolius*). By contrast, the focal species of mobile dune macrohabitats showed different responses along the $CaCO_3$ gradient with highest probabilities of occurrence at high (*A. arenaria*), low (*Anthemis maritima*) and medium values (E. spinosa).

4. Discussion

To the best of our knowledge, this is the first study that has successfully modelled the probability of occurrence of focal plant species on edaphic gradients in Mediterranean coastal dunes. We used soil factors as predictors to identify the edaphic requirements of focal dune plants, in contrast with other studies that quantified dune species and community specialization on the basis of proxies of environmental gradients (e.g. Carboni et al., 2016).

Our results confirm that soil variables play a main role in driving plant species composition on sandy Mediterranean coasts (Nordstrom et al., 2009; Fenu et al., 2013; Angiolini et al., 2013; Ruocco et al., 2014). Although the total variation explained by CCA and GAMs was relatively low, this is a common finding in such analyses and may simply reflect a lack of fit of the model to the data; it suggests that interpretation should be focused on the relative importance of the explanatory variables (Økland, 1999). On the other hand, the result can reflect the large number of environmental factors that act in complex coastal ecosystems (Ciccarelli et al., 2014; Ruocco et al., 2014). Our models indicated that most of the information on focal dune species composition was contained in very few soil factors, in line with studies conducted in other dune systems around the world (Houle, 2008; Ihm et al., 2007; Brunbjerg et al., 2012) as well as in other Mediterranean dune systems (Ozcan, 2010; Angiolini et al., 2013). The factors that sufficiently explained species composition patterns along the coast in the study areas included FC, pH and $CaCO_3$. Focal species of each macrohabitat clustered in different parts of CCA ordination space, confirming their ecological specialization (Carboni et al., 2016). The key role of the sea-inland gradient in coastal dune ecosystems, along which opposite trends of pH and FC were observed, as found also by Kim and Yu (2009), was highlighted by the shifting of focal species along the second CCA axis from embryo dune to fixed dune macrohabitats.

Field capacity (FC), which can be considered a proxy for substrate water content, proved to be the main factor determining dunal species composition, with species of embryo dune macrohabitat linked to low values, and those of fixed dune macrohabitats linked to high values. This result is in line with the concept that substrate water content is a major limiting factors for plant growth in sandy soils, where porosity is high and FC low (Maun, 2009). pH and $CaCO_3$ were confirmed to be factors playing a significant role in dune focal species distribution (Proovost et al., 2004; Angiolini et al., 2013; Fenu et al., 2012) with soils further from the coast having lower limestone content and lower pH due to shelter from marine aerosol deposition (Peltier et al., 2001; Maun 2009), two ecological conditions suitable for species of fixed dune macrohabitats.

The contribution of TOC as a predictor of dune focal species assemblages was not significant, contrary to reports by various authors (Lee et al. 2007; Ruocco et al., 2014; Brunbjerg et al., 2012; Fenu et al., 2013). However, in the macrohabitats examined, TOC increased from embryo dunes to fixed dunes along the sea-inland gradient, corresponding to an increase in vegetation richness and cover linked to accumulation of litter, which plays an important role in edaphic changes in these ecosystems (Isermann, 2005; Ruocco et al., 2014) and has a significant simple effect. Since soils poor in organic matter also have low field capacity whereas soil organic matter increases this variable (Kutiel, 1998), it is not surprising that the conditional effect of TOC decreased dramatically when FC was added to the model. To finish, EC, TC and TN do not have a major influence on focal dune species composition. The insignificant effect of EC in particular is surprising, since its decrease along the sea-inland gradient (Maun, 2009) notoriously drives vegetation zonation also in Mediterranean coastal ecosystems (Angiolini et al., 2013; Fenu et al., 2012, 2013; Muňoz-Vallés et al., 2015). However, the fact that only part of the sea-inland gradient was taken into account in the present study (wooded dunes and salt marshes were excluded), combined with the fact that airborne rather than soil salinity can limit plant growth in coastal dunes (Rozema et al., 1985), may be reasons why it was of minor importance.

The GAM results quantified the link between focal dune species probability of occurrence and variations in single soil factors. Response curves along soil gradients could be interpreted ecologically and identified species with similar or different edaphic requirements. According to CCA, FC was the factor explaining most of the variance in species occurrence. The focal species of fixed dunes (i.e. *Juniperus oxycedrus* ssp. *macrocarpa*, *Phillyrea angustifolia* and *Helichrysum stoechas*) showed overlapping ecological requirements with respect to FC, a monotonic increase and maximum responses in soils with higher moisture (high FC), demonstrating their role as indicators of fixed dunes where the soil is more structured and developed, becoming suitable for sand dune specialist species (Carboni et al., 2016). On the other hand, the probability of occurrence of annual mobile dune species, such as *Lagurus ovatus* and *Vulpia membranacea*, was high at low values of FC. These entities are part of communities that play an important role in replacing the perennial plant communities of mobile dunes and fixed dunes (Ercole et al., 2007) and, precisely because of their pioneer nature, they are related to sandy and arid soils. Embryo dune species such as *S. virginicus*, *Cakile maritima* and *E. farctus* showed a very specific ecological requirement with respect to pH, with monotonic increasing responses, while fixed dune species showed the opposite trend. Moreover, *Ammophila arenaria*, the main focal species of mobile dunes, showed a unimodal response to pH with maximum probability of occurrence at average values. Considering the different FC and pH requirements of species of different macrohabitats, these two variables can be considered the most

decisive factors indicating clear differences in dune species ecological needs among macrohabitats. However, species of embryo dunes and fixed dunes also showed significantly different ecological requirements with respect to TOC, which was not included in the CCA model. Pioneer species of embryo dunes, such as *Salsola kali*, *Euphorbia paralias* and *E. spinosa*, had maximum probability of occurrence at low TOC values, while those of fixed dunes, such as *Lagurus ovatus* and *Smilax aspera*, showed the opposite trend, in line with the increase in TOC from shoreline to inland reported in the literature (Sykora et al., 2004; Fenu et al., 2012, 2013; Ruocco, 2014). Species of mobile dunes, such as *Medicago marina* and *Echinophora spinosa*, showed high probabilities of occurrence with low EC, while some species of fixed dunes proved to tolerate slightly higher values, according to the presence of entities with wider ecological range (Carboni et al., 2016). Dune focal species diagnostic for the same macrohabitat therefore tend to have: (i) similar ecological soil requirements; (ii) niche segregation among macrohabitats, in line with their different position in the vegetation succession (Acosta et al., 2005; Forey et al., 2008); (iii) overlapping edaphic niches within macrohabitats with dominance of stress and disturbance rather than competition as major structuring factors (Macedo et al., 2010; Ciccarelli, 2015). However, the probability of occurrence of certain species typical of mobile dune, significantly affected by $CaCO_3$, highlighted species niche segregation within the given macrohabitat, probably as a result of competition for physical space with the competitive, stress tolerant species *A. arenaria* (Ciccarelli, 2015). *Anthemis maritima* and *Vulpia fasciculata*, showing greater ecological plasticity (Spanò et al., 2013), can live where the habitat becomes unsuitable for *A. arenaria*, namely at medium-low $CaCO_3$ values. The latter species, considered constructor and main diagnostic species of mobile dunes, cannot therefore be used as indicator of the ecological requirements of the whole community.

5. Conclusions

Dune vegetation, which is commonly formed by a reduced set of specialized species, clearly benefits from soil factors that determine the probability of occurrence of focal plants. Although sand dune ecosystems have greater complexity and variability than indicated by soil factors alone, our study contributes in three ways to the goal of conservation and/or management of these habitats in the Mediterranean basin: (i) it confirms the key role of soil factors in driving dune plant species composition in the Mediterranean area; (ii) it highlights the role of soil water content as a main factor affecting focal species distribution in sandy soils, at the same time confirming the determining function of pH and $CaCO_3$; (iii) it offers insights into the edaphic needs of dune focal species in terms

of soil factors, helping explain their niche segregation among macrohabitats. Moreover, in some cases different ecological responses occur within macrohabitats due to species competition.

Without appropriate conservation efforts, focal species of dune habitats, specialized with respect to soil factors, may well disappear solely in response to changes in edaphic conditions caused by climate change or human pressure. Our models highlight these narrow edaphic requirements and generally support the role of focal dune species as bio-indicators of soil conditions. The results of our study can be put into practice by exploiting evidence that species can be used to detect soil changes in coastal dune ecosystems to design programs to monitor habitat ecological trends with the objective of preventing disappearance of these coastal habitats.

General conclusions

Different strategies and tools can be used for the same goal, but inappropriate management actions can yield little, leading to wrong results and missed conservation targets. This thesis, based on scientific methods, has generated interesting results with which conservation policies can be implemented and good management practices can be established. In particular, the results of the first chapter indicate that conservation management should comprise the traditional practices that historically contributed to form the diversity of semi-natural grasslands in the White Carpathians. Hence, optimal management should be heterogeneous by including wide variety of practices in a mosaic or in different times during the season. Moreover, grazing may not be optimal for traditional hay-meadows and mowing should be practiced similarly as in the pre-intensive farmland, creating spatio-temporal heterogeneity rather than uniformly cut large grassland areas during a short period. The second chapter indicates that species-specific management is not required for different pine forest types but a farsighted management path should take into account actions at the species level, understood in terms of zonation along the sea-inland gradient. In fact, coastal dune vegetation succession is relatively maintained in coastal pine stands and management should consider the understorey of Mediterranean pine stands. The third chapter results show that soil features were not of primary importance for below-ground and above-ground community assemblages. In the light of these findings and ongoing threats in coastal areas, the recommendation for management measures are directed at maintenance of diversified vegetation structure, which may ensure above-ground and below-ground biodiversity with diverse biological community assemblages. To finish, the fourth chapter demonstrates that dune focal species, diagnostic of different macrohabitats, have different ecological responses with respect to soil factors. Moreover, species within the same habitat can have different ecological responses due to species competition. Data about edaphic requirements of sand dune species and modelling of their ecological responses suggests that focal dune species can be bio-indicators of soil conditions and provide useful indications for conservation, monitoring and restoration of Mediterranean coastal habitats.

In conclusion, from the use of concordance to ecological proxies, from habitat to species level, the thesis provides necessary and substantial management actions for nature conservation, dealing with different concerns and new challenges. The findings of this thesis should not be disregarded, since they have implications for management planning and conservation, contributing to the advancement of knowledge in these applied fields.

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Collateral activities

During the three years 2013-2016 the following publications were also published.

Other publications

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Appendices

Appendix A. Supplementary materials to Chapter 1.

Table S1 List of study sites in the White Carpathians. Site and its ID, perimeter, area, latitude, longitude and elevation are reported for each site. Latitude and longitude refer to the central point of each site.

ID	Site	Perimeter	Area	Latitude	Longitude	Elevation
		m	m^2	N (WGS 84)	E (WGS 84)	m a.s.l.
1	Starohrozenkovský lom	753	26843	48.972803	17.870084	484
2	Kladná	557	14914	49.090313	17.787419	356
3	U Petrůvky	10103	40576	49.109220	17.811349	417
4	Štítná – stráň nad dráhou	1502	83520	49.076489	17.982622	348
5	Ploščiny	1815	73385	49.139740	18.060577	654
6	Záhumenice	3083	281140	48.891584	17.683516	599
7	Bylnice – Na stráži	505	15173	49.078048	18.007920	337
8	Suchov – nad Ostrožankou	964	53208	48.901244	17.577197	444
9	Nová hora	906	27463	48.890463	17.723117	434
10	Bílé potoky	2934	53158	49.117550	18.024679	358
11	Podhradské louky	1103	76334	48.887143	17.558201	527
12	Mechnáčky	778	30295	48.883293	17.703279	391
13	Cestiska	678	22508	48.928440	17.730745	497
14	Kaňoury	1178	70663	49.113934	18.106402	581
15	Javorník – pod Hradiskem	821	29461	48.863390	17.542314	406
16	Žerotín	972	20804	48.862588	17.327336	256
17	Hutě	1474	58024	48.992245	17.909051	544
18	V Krátkých	1715	53236	48.958191	17.823986	536
19	Kútky	1758	124712	48.831339	17.382482	441
20	U Megovky	918	24275	48.849603	17.582044	456
21	Podlučí	1626	70386	48.866545	17.449972	317
22	Končiny	1441	86281	48.868164	17.618532	456
23	Drahy	2167	112982	48.921277	17.640415	393
24	Machová	3069	301347	48.824122	17.524863	435
25	Rybnické údolí pod Machovou	1362	35964	48.829836	17.542059	469
26	Přední louky	2402	176194	48.882810	17.602651	433
27	Dolnoněmčanské louky	1546	61351	48.897474	17.632372	539
28	Paseky u Nedašovy Lhoty	1346	30344	49.128763	18.098915	607
29	Sidonie – pastvina na hranici	1451	87441	49.059829	18.091622	405
30	Javorina	624	22934	48.855585	17.668989	899
31	Jamy u Březové	1427	82604	48.920255	17.731195	483
32	Lopenické sedlo	4983	706452	48.938793	17.797765	638
33	Skleněný vrch	868	27357	48.876275	17.411486	348
34	Hrnčárky	692	21936	48.908774	17.676318	458

Supplementary text S1 Vegetation types of the study sites (phytosociological nomenclature of plant communities follows Chytrý (2007, 2011).

The commonest grassland vegetation among the study sites was a semi-dry grassland of the *Brachypodio pinnati-Molinietum arundinaceae*, a transitional association between the *Bromion erecti* and *Cirsio-Brachypodion pinnati* alliances. This vegetation type was found in 19 of the total of 34 study sites. Regular mowing once a year in summer is the main management of this grassland type. The second commonest vegetation type, found at 10 of 34 sites, was mesophilous grassland of *Anthoxantho odorati-Agrostietum tenuis*, a transitional association between the *Cynosurion cristati* and *Arrhenatherion elatioris* alliances. For this vegetation, both mowing and grazing has been common management, depending on site conditions, accessibility and farmers' needs. Further vegetation types included *Scabioso ochroleucae-Brachypodietum pinnati* (*Cirsio-Brachypodion pinnati*; 7 sites, usually mown at present but partly grazed in the past), *Polygalo majoris-Brachypodietum pinnati* (*Cirsio-Brachypodion pinnati*; 1 site) and *Festuco capillatae-Nardetum strictae* (*Violion caninae*; 1 site); the latter two respectively represented the driest and the most acidophilous grassland type in the study area and were both mown once a year. At many sites, however, transitional vegetation between two or more of these grassland types occurred. Additionally to the above mentioned associations, also transitions to *Ranunculo bulbosi-Arrhenatheretum elatioris* or, rarely, to *Poo-Trisetetum flavescentis* associations from the *Arrhenatherion elatioris* alliance, and to *Campanulo rotundifoliae-Dianthetum deltoidis* association from the *Violion caninae* alliance occurred. At one site, successional semi-dry grassland stage occurred.

Furthermore, in addition to the prevailing semi-dry grasslands, small patches with various types of wetlands were found in nearly half of the study sites. Most often, these were calcium-rich spring fens of the *Caricion davallianae* alliance (predominantly the association *Carici flavae-Cratoneuretum filicini*), sometimes disturbed and eutrophicated to some degree, forming a transitional vegetation to the *Calthion palustris* alliance classified as the *Junco inflexi-Menthetum longifoliae* association. At some of the sites, also other associations from the *Calthion palustris* alliance were developed (*Cirsietum rivularis*, *Angelico sylvestris-Cirsietum oleracei*, *Scirpetum sylvatici* and *Filipendulo ulmariae-Geranietum palustris*), and, exceptionally, *Molinietum caeruleae* association from the *Molinion caeruleae* alliance and *Holcetum lanati* association from the *Deschampsion cespitosae* alliance were found. Most of these moist places were mown once a year (including biomass removal), usually in the late summer.

A rather constant component of the sites were also various scattered trees and shrubs (sometimes forming small groups). At some also larger patches of woodland or scrub occurred.

Table S2 Detailed overview of grassland vegetation types at individual study sites. – **Semi-dry grasslands** comprise several associations from the *Bromion erecti* and *Cirsio pannonicae-Brachypodion pinnati* alliances including various transitions; **mesic meadows** comprise mostly *Anthoxantho odorati-Agrostietum tenuis* association including transitions to other associations of the *Arrhenatherion elatioris*, *Cynosurion cristati* and *Violion caninae* alliances; **wet to intermittently wet meadows** are represented by some associations and transitional vegetation types of the *Calthion palustris*, *Molinion caeruleae* and *Deschampsion cespitosae* alliances; **spring fens** belong mostly to the association of *Carici flavae-Cratoneuretum filicini* from the *Caricion davallianae* alliance. **Scrub and woodland patches** do not include scattered solitary trees or shrubs and fruit trees. **„1“** = occupying a considerable proportion of the site; **„+“** = rare occurrence.

ID	Site	Semi-dry grasslands	Mesic meadows	Wet to intermittently wet meadows	Spring fens	Scrub and woodland patches
1	Starohrozenkovský lom	1	1			1
2	Kladná		1			
3	U Petrůvky		1			+
4	Štítná – stráň nad dráhou	1	1			1
5	Ploščiny	1	1		+	1
6	Záhumenice	1	1			1
7	Bylnice – Na stráži	1	1			+
8	Suchov – nad Ostrožankou	1	+			1
9	Nová hora	1	+			1
10	Bílé potoky	1		1	+	1
11	Podhradské louky	1	1			
12	Mechnáčky	1	1	+		1
13	Cestiska	1				+
14	Kaňoury	1	1			+
15	Javorník – pod Hradiskem	1				1
16	Žerotín	1				1
17	Hutě		1	+	+	+
18	V Krátkých	1	1	1	+	+
19	Kútky	1		1		+
20	U Megovky	1		1	1	+
21	Podlučí	1				1
22	Končiny	1			+	
23	Drahy	1			+	1
24	Machová	1		+		1
25	Rybnické údolí pod Machovou	1		+	+	+
26	Přední louky	1				+
27	Dolnoněmčanské louky	1		+		+
28	Paseky u Nedašovy Lhoty		1			+
29	Sidonie – pastvina na hranici		1			+
30	Javorina		1			
31	Jamy u Březové	1	+		+	1
32	Lopenické sedlo		1	+	+	+
33	Skleněný vrch	1	+			1
34	Hrnčárky	1		1	1	1

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Supplementary text S2 Sampling methods, data preparation and nomenclature.

Plants

Vascular plants were recorded during one visit at each site in June and early July in a 1-ha plot with shape differing according to the relief and woodland distribution, in order to avoid woodland and larger scrub patches. Information on individual species abundances was recorded on an ordinal scale: 1 – sporadic; 2 – rare, covering up to 5% of the plot; 3 – scattered, 5–15% of the plot; 4 – common, 15–25% of the plot; 5 – dominant or subdominant, over 25% of the plot. Survey time for each site was 4–5 hours, depending on local diversity. The plant species were classified in two categories according to their affinity to open habitats in the study area (Table S6): (i) open country species – most herbs and chamaephytes (including also many species known from open forests in other regions but occurring in open grasslands in the White Carpathians), and (ii) woodland species – herb species preferring closed forests or scrub in the region, and all woody species (excluding most of the chamaephytes). Nomenclature follows Danihelka et al. (2012).

Butterflies and moths

Butterflies and moths (Lepidoptera) were surveyed in 2007–2010 for two consecutive years at each site, including at least six visits in growing season (April–October), with an interval of about four weeks, depending on the weather conditions. Data for diurnal Lepidoptera (including butterflies – Papilionoidea and Hesperioidea, burnet moths – Zygaenidae, and picture-winged leaf moths – Thyrididae, collectively referred for simplicity to as 'butterflies' in the paper) were recorded by timed-surveys (Royer et al., 1998; Kadlec et al., 2012), i.e. thorough searches throughout the study site with no fixed survey path, attempting to spot as many species/individuals as possible, paying preferential attention to nectar-rich patches. The survey duration was standardized to two hours per visit and site, preferably between 10:00 and 14:00, i.e. during the highest flight activity.

Nocturnal Lepidoptera (collectively referred to as 'moths' in the paper) were sampled using light trapping. The main source of directional UV light used at each site was a mercury vapour lamp (Tesla RVC 125 W or Tesla RVC 250 W; Tesla, Praha-Holešovice, Czech Republic) powered by a petrol generator (Honda EX650; American Honda Motor Co. Ltd., Duluth, Georgia, USA). The arriving moths were collected on lighted canvas. In the parts of each collecting site where this main light source was obscured by relief or trees and shrubs, additional smaller light traps were used, composed of a UV fluorescent tube (Sylvania T5 F8W / BL350, Havells Sylvania Europe Ltd., London, UK; or Philips T5 8W, Philips Lighting, Netherlands) powered from a 12 V DC battery, and provided with a plastic basket containing a vial with chloroform at the bottom to kill the attracted insects. All the light sources were located in the same places at each site throughout the study. The light-trapping always started after sunset, about half an hour before dusk and usually ended four hours later or after a sudden deterioration of weather conditions such as an abrupt decrease of temperature or arrival of a strong wind. Material of the following families of Lepidoptera was collected and evaluated under "moths": Brahmaeidae, Cossidae, Drepanidae, Endromidae, Erebidae, Geometridae, Hepialidae, Lasiocampidae, Limacodidae, Noctuidae, Nolidae, Notodontidae, Psychidae, Saturniidae, and Sphingidae. Light trapping is known to attract moths from a distance of ca. 50–200 m depending on habitat characteristics (Wirooks, 2006). Although it works most effectively for species developing in close surroundings of the light source and these species usually make up the largest portion of the samples, non-indigenous or "tourist" species of moths developing in more distant habitats, such as forests or agricultural fields in our case, are usually collected too (Wirooks, 2005). Moreover, the White Carpathian grasslands usually comprise quite high proportion of solitary trees and shrubs and are often surrounded or interspersed by woodland. Larvae of many species of moths develop on woody plants and many of them were light-trapped in fairly high numbers at our sites and can be considered as indigenous to the White Carpathian grassland landscape. These species are, however, less likely to be affected by grassland management than species developing directly in the grassland on herbs or in litter. For these reasons, we analysed separately the data from total catches and then a

subset of the dataset including only the moth species which are known to develop in open-country habitats such as grasslands and herbaceous woodland fringes, not considering the species associated with woody plants or herbs growing in closed forests (Table S8). The corresponding information on the moth species biology was extracted from regional monographs (Macek et al., 2007; 2008; 2012). Similarly, open-country species of butterflies were evaluated separately based on the information from Macek et al. (2015). Nomenclature of Lepidoptera follows Laštůvka and Liška (2011).

Orthopterans

Orthopterans (grasshoppers, bushcrickets and crickets) were sampled by timed-surveys (2–3 hours/site) during two visits at each site in a single season (all sites together were sampled in 2006–2010), one in the early summer and the other in the late summer, which are the main periods of occurrence of adults in central Europe. Sweeping, direct visual and acoustic observations were combined on each visit. The information on biology of individual species for the distinction between open-country and woodland species (Table S9) was extracted from Kočárek et al. (2013). Holuša et al. (2013) was followed for the nomenclature of Orthoptera.

Ground beetles

Ground beetles (Coleoptera: Carabidae) were sampled using pitfall traps. Thirteen traps (0.5 l volume, partly filled with 10% ethylene glycol as a fixative and provided with rain cover) were used per site and arranged in a linear transect at 10 m intervals. The trap content was collected every 3–4 weeks from April to the beginning of October. Each site was surveyed for one season during the years 2008–2010. The distinction between open-country and woodland species (Table S10) is based on Resl (2008) and Hůrka (1996). Nomenclature follows Löbl and Smetana (2003).

Preparation of insect data for analyses

All insect data acquired on different sampling dates throughout the surveys were merged to create a single species list for each site. The individual species abundances were expressed on an ordinal scale (1 – 1 specimen; 2 – 2–10 specimens; 3 – 11–50 specimens; 4 – 51–100 specimens; 5 – >100 specimens; for orthopterans, only three categories were distinguished: 1 – 1–3 specimens; 2 – rare, up to about 10 specimens; 3 – common, tens of specimens), keeping only the maximum abundance recorded at any single sampling date for species collected repeatedly at the same site. Logistical issues prevented repeated sampling at a few sites (3 sites for butterflies, moths, and ground beetles, 1 site for orthopterans) and the data from these incompletely sampled sites were not used for the analyses.

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Table S3 Environmental data: **Management** (Grazing; Mowing; Abandoned; Mixed) and **Climate** (Mean annual temperature; Total annual precipitation; Total growing season radiation). See Material and methods for explanations.

		Management				Climate		
ID	**Site**	**Mowing**	**Grazing**	**Abandoned**	**Mixed**	**Mean annual temperature**	**Total annual precipitation**	**Total growing season radiation**
						°C	mm	Wh/m^2
1	Starohrozenkovský lom	1	0	2	1	7.5	803.8	876190.8
2	Kladná	0	2	0	0	7.9	760.9	879615.3
3	U Petrůvky	2	0	0	0	7.7	777.2	754601.6
4	Štítná – stráň nad dráhou	1	0	1	2	8.2	762.4	856440.1
5	Ploščiny	1	2	0	1	6.7	862.3	852085.6
6	Záhumenice	2	0	1	1	7.3	859.4	782125.8
7	Bylnice – Na stráži	1	1	0	1	8.2	758.0	849702.5
8	Suchov – nad Ostrožankou	1	0	2	1	7.7	775.0	815782.1
9	Nová hora	2	0	0	1	7.7	782.8	858387
10	Bílé potoky	2	1	0	1	7.5	804.9	833666.5
11	Podhradské louky	2	0	0	0	7.7	775.8	864892.8
12	Mechnáčky	2	0	1	1	7.6	813.3	879407.4
13	Cestiska	2	0	1	2	7.5	825.5	863435.2
14	Kaňoury	2	0	1	2	6.7	859.4	877571.9
15	Javorník – pod Hradiskem	0	0	2	0	7.8	740.8	755495.1
16	Žerotín	2	0	1	2	8.7	533.4	807910.6
17	Hutě	2	1	1	2	7.3	822.6	787926.9
18	V Krátkých	2	0	0	1	7.3	839.0	850570.9
19	Kútky	2	1	0	1	7.8	665.4	839347.7
20	U Megovky	2	0	0	1	7.4	849.9	839405.9
21	Podlučí	2	0	1	2	8.2	647.8	813522.2
22	Končiny	2	0	1	1	7.4	848.8	807332.4
23	Drahy	1	1	1	2	7.8	771.8	797517
24	Machová	2	0	0	1	7.8	750.6	765876.5
25	Rybnické údolí pod Machovou	2	0	0	1	7.6	789.5	831162.5
26	Přední louky	2	0	1	2	7.6	796.3	801118.3
27	Dolnoněmčanské louky	2	0	1	1	7.3	861.4	853212.3

28	Paseky u Nedašovy Lhoty	0	2	1	2	6.7	864.7	895402.3
29	Sidonie – pastvina na hranici	0	0	2	0	7.2	824.9	887081.8
30	Javorina	2	0	1	1	6.6	1004.6	801452
31	Jamy u Březové	0	1	1	1	7.6	810.9	817933.7
32	Lopenické sedlo	1	2	0	1	6.8	903.5	713628.4
33	Skleněný vrch	2	0	0	1	8.3	600.9	810010
34	Hrnčárky	2	0	0	2	7.52	827.8	870226.5

Table S4 Environmental data: **Landscape context** (Landcover within 1 km from the site: Forest/Grassland/Arable land/Settlement; Local habitat heterogeneity; Cover of woody species; Landscape heterogeneity – Shannon index; Table S4). See Material and methods for explanations.

		Landscape context						
ID	**Site**	**Forest (within 1 km)**	**Grassland (within 1 km)**	**Arable land (within 1 km)**	**Settlement (within 1 km)**	**Local habitat heterogeneity (grassland types)**	**Cover of woody species (within site + 25 m buffer)**	**Landscape heterogeneity (Shannon index)**
		%	%	%	%		%	
1	Starohrozenkovský lom	32.56	44.11	14.35	8.98	2	55	1.22
2	Kladná	41.73	34.19	16.22	7.86	1	25	1.23
3	U Petrůvky	56.20	14.97	28.78	0.05	1	45	0.97
4	Štítná – stráň nad dráhou	14.62	30.39	43.53	11.45	2	20	1.25
5	Ploščiny	89.35	10.65	0.00	0.00	3	55	0.34
6	Záhumenice	47.28	41.89	10.83	0.00	2	20	0.96
7	Bylnice – Na stráži	12.87	28.97	33.97	24.19	2	20	1.33
8	Suchov – nad Ostrožankou	39.64	44.49	13.01	2.86	2	70	1.09
9	Nová hora	31.96	47.75	7.18	13.12	2	40	1.17
10	Bílé potoky	90.01	8.26	1.22	0.51	3	65	0.38
11	Podhradské louky	67.16	32.69	0.16	0.00	2	30	0.64
12	Mechnáčky	57.61	36.75	3.49	2.15	3	40	0.89
13	Cestiska	34.39	34.13	16.54	14.94	1	30	1.32
14	Kaňoury	48.27	45.35	6.38	0.00	2	40	0.89
15	Javorník – pod Hradiskem	31.31	42.49	14.73	11.47	1	40	1.26
16	Žerotín	20.27	31.72	41.36	6.64	2	40	1.23
17	Hutě	56.87	22.98	18.54	1.60	3	35	1.04
18	V Krátkých	36.15	61.21	1.42	1.22	4	40	0.78
19	Kútky	50.99	44.52	3.20	1.29	2	25	0.87
20	U Megovky	62.50	36.78	0.53	0.18	3	50	0.70
21	Podlučí	29.56	17.24	53.20	0.00	1	35	1.00
22	Končiny	62.26	14.85	22.26	0.64	2	35	0.94
23	Drahy	47.49	35.71	16.31	0.49	3	25	1.04
24	Machová	34.83	52.35	12.62	0.20	2	30	0.98
25	Rybnické údolí pod Machovou	66.76	30.69	2.55	0.00	3	45	0.73

26	Přední louky	42.78	48.31	4.37	4.54	1	20	0.99
27	Dolnoněmčanské louky	80.22	19.78	0.00	0.00	2	50	0.50
28	Paseky u Nedašovy Lhoty	28.92	48.63	17.87	4.58	1	45	1.16
29	Sidonie – pastvina na hranici	88.82	7.91	0.00	3.27	1	30	0.42
30	Javorina	85.68	14.32	0.00	0.00	1	20	0.41
31	Jamy u Březové	35.48	37.19	13.90	13.43	3	20	1.28
32	Lopenické sedlo	59.09	37.93	2.35	0.63	3	15	0.80
33	Skleněný vrch	36.42	18.98	42.82	1.78	2	60	1.12
34	Hrnčárky	60.82	8.69	30.13	0.36	3	50	0.90

Table S5 Definition of the land-cover categories through the habitat types according to Chytrý et al. (2010) recorded in field-based mapping for Natura 2000 and through the CORINE land-cover classes according to Bossard et al. (2000).

	Natura 2000 (biotope 1 and 2)	**CORINE land-cover classes**
Grassland	T1.1, T1.3, T1.4, T1.5, T1.6, T1.9, T1.10, T2.3B, T3.4A, T3.4B, T3.4C, T3.4D, T4.1, T4.2, T5.5, X5, X7A, X7B, R1.1, R1.2, R2.1	231, 321
Forest	X8, X9A, X9B, X10, X11, X12, X13, R1.3, R1.4, K1, K2.1, K3, L2.2A, L2.2B, L3.3A, L3.3B, L3.4, L4, L5.1, L5.4, L6.1, L6.4, L7.1	311, 312, 313, 324
Arable land	X2, X3, X4	211, 222, 242, 243
Settlement	X1, X6	112, 121
Not evaluated	V1F, V1G, V2A, V4B, V5, X14, M1.1, M1.2, M1.5, M1.7, M2.3	

References

Bossard, M., Feranec, J., Otahel J., 2000. CORINE Land Cover technical guide: addendum 2000. European Environment Agency, Copenhagen.

Chytrý, M., Kučera, T., Kočí, M., Grulich V., Lustyk P. (Eds.) 2010. Katalog biotopù České republiky. (Habitat Catalogue of the Czech Republic.) 2nd edition. Agentura ochrany přírody a krajina ČR, Praha, 445 pp. (in Czech, English summary).

Supplementary text S3 R script for the calculations of variation partitioning and the amount of variation explained by individual management types.

```
#### Management of semi-natural grasslands benefiting both plant and insect diversity: the importance of heterogeneity and tradition
#### Script for calculating species richness analysis
#### Authors: David Zelený & Gianmaria Bonari

### Import species and environmental data ----
spe <- read.delim ('species-data.txt', row.names = 1)
env <- read.delim ('env-data.txt', row.names = 1)

#### Definition of functions ----
### Definition of function calculating D2 & adjD2 ----


adjD2 <- function (glm.temp)  # see also ecospat.adj.D2.glm at https://github.com/cran/ecospat/blob/master/R/ecospat.adj.D2.R
{
  RD <- glm.temp$deviance
  ND <- glm.temp$null.deviance
  D2 <- (ND-RD)/ND
  n <- length (glm.temp$y)
  p <- length (glm.temp$coefficients)
  adjD2 <- 1-((n-1)/(n-p))*(1-D2)
  return (list (D2 = D2, adjD2 = adjD2))
}

### Definition of glm.varpart function ----
glm.varpart <- function (dep, env, nperm = 999)
{
  env <- as.data.frame (cbind (dep = dep, env))
  M <- adjD2 (glm (dep ~ graz + mown + aban + mosa, data = env, family = quasipoisson))
  C <- adjD2 (glm (dep ~ tmpr + precip + rad, data = env, family = quasipoisson))
  L <- adjD2 (glm (dep ~ g + Shannon + hab + cover, data = env, family = quasipoisson))
  MC <- adjD2 (glm (dep ~ graz + mown + aban + mosa + tmpr + precip + rad, data = env, family = quasipoisson))
  CL <-adjD2 (glm (dep ~ tmpr + precip + rad + g + Shannon + hab + cover, data = env,
                   family = quasipoisson))
  LM <-adjD2 (glm (dep ~ g + Shannon + hab + cover + graz + mown + aban + mosa, data =
                     env, family = quasipoisson))
  MCL <-adjD2 (glm (dep ~ graz + mown + aban + mosa + tmpr + precip +
                      rad + g + Shannon + hab + cover, data = env, family = quasipoisson))

  # calculates original D2
  a.D2 <- MCL$D2 - CL$D2  # pure management
  b.D2 <- MCL$D2 - LM$D2  # pure climate
  c.D2 <- MCL$D2 - MC$D2  # pure landscape
  ge.D2 <- M$D2 + C$D2 - MC$D2
  gf.D2 <- C$D2 + L$D2 - CL$D2
  gd.D2 <- L$D2 + M$D2 - LM$D2
```

```
  ggdef.D2 <- M$D2 + C$D2 + L$D2 - MCL$D2
  g.D2 <- ge.D2 + gf.D2 + gd.D2 - ggdef.D2
  d.D2 <- gd.D2 - g.D2
  e.D2 <- ge.D2 - g.D2
  f.D2 <- gf.D2 - g.D2

  # adjusted D2
  a.adjD2 <- MCL$adjD2 - CL$adjD2  # pure management
  b.adjD2 <- MCL$adjD2 - LM$adjD2  # pure climate
  c.adjD2 <- MCL$adjD2 - MC$adjD2  # pure landscape
  ge.adjD2 <- M$adjD2 + C$adjD2 - MC$adjD2
  gf.adjD2 <- C$adjD2 + L$adjD2 - CL$adjD2
  gd.adjD2 <- L$adjD2 + M$adjD2 - LM$adjD2
  ggdef.adjD2 <- M$adjD2 + C$adjD2 + L$adjD2 - MCL$adjD2
  g.adjD2 <- ge.adjD2 + gf.adjD2 + gd.adjD2 - ggdef.adjD2
  d.adjD2 <- gd.adjD2 - g.adjD2
  e.adjD2 <- ge.adjD2 - g.adjD2
  f.adjD2 <- gf.adjD2 - g.adjD2

  null.glm <- glm (dep ~ 1, data = env, family = quasipoisson)
  MC.glm <- glm (dep ~ graz + mown + aban + mosa + tmpr + precip + rad, data = env, family =
quasipoisson)
  CL.glm <- glm (dep ~ tmpr + precip + rad + g + Shannon + hab + cover, data = env, family =
quasipoisson)
  LM.glm <-glm (dep ~ g + Shannon + hab + cover + graz + mown + aban + mosa, data = env,
family = quasipoisson)
  MCL.glm <-glm (dep ~ graz + mown + aban + mosa + tmpr + precip + rad + g + Shannon + hab +
cover, data = env, family = quasipoisson)
  all.P <- anova (null.glm, MCL.glm, test = 'Chi')$P[2]
  a.P <- anova (CL.glm, MCL.glm, test = 'Chi')$P[2]  # significance of pure management - [a]
  b.P <- anova (LM.glm, MCL.glm, test = 'Chi')$P[2]  # significance of pure climate - [b]
  c.P <- anova (MC.glm, MCL.glm, test = 'Chi')$P[2]  # significance of pure landuse - [c]
  return (list (D2 = data.frame (a = a.D2, b = b.D2, c = c.D2, d = d.D2, e = e.D2, f = f.D2, g = g.D2,
h = 1 - MCL$D2, MCL = MCL$D2), adjD2 = data.frame (a = a.adjD2, b = b.adjD2, c = c.adjD2, d
= d.adjD2, e = e.adjD2, f = f.adjD2, g = g.adjD2, h = 1 - MCL$adjD2, MCL = MCL$adjD2), P =
data.frame (a.P = a.P, b.P = b.P, c.P = c.P, all.P = all.P), P.star = data.frame (a.P.star = signif.stars
(a.P), b.P.star = signif.stars (b.P), c.P.star = signif.stars (c.P), all.P.star = signif.stars (all.P))))
}


### Definition of function replacing significance by stars (inspired by: print.summary.glm) ----
signif.stars <- function (pv)
{
  Signif <- symnum(pv, corr = FALSE, na = FALSE,
                   cutpoints = c(0, 0.001, 0.01, 0.05, 0.1, 1),
                   symbols = c("***", "**", "*", ".", " "))
  format(Signif)
}

### Definition of function for explained variation of individual management treatment - regression
coefficients, gross and pure effects + test of significance (for explained variation) ----
```

```
expldev.multireg <- function (dep, env)
{
  glm.CL <- glm (dep ~ tmpr + precip + rad + g + Shannon + hab + cover, data = env, family =
quasipoisson)
  glm.CL.gr <- glm (dep ~ graz + tmpr + precip + rad + g + Shannon + hab + cover, data = env,
family = quasipoisson)
  glm.CL.mw <- glm (dep ~ mown + tmpr + precip + rad + g + Shannon + hab + cover, data = env,
family = quasipoisson)
  glm.CL.ab <- glm (dep ~ aban + tmpr + precip + rad + g + Shannon + hab + cover, data = env,
family = quasipoisson)
  glm.CL.ms <- glm (dep ~ mosa + tmpr + precip + rad + g + Shannon + hab + cover, data = env,
family = quasipoisson)
  glm.CL.mw.ab.ms <- glm (dep ~ mown + aban + mosa + tmpr + precip + rad + g + Shannon + hab
+ cover, data = env, family = quasipoisson)
  glm.CL.gr.ab.ms <- glm (dep ~ graz + aban + mosa + tmpr + precip + rad + g + Shannon + hab +
cover, data = env, family = quasipoisson)
  glm.CL.gr.mw.ms <- glm (dep ~ graz + mown + mosa + tmpr + precip + rad + g + Shannon + hab
+ cover, data = env, family = quasipoisson)
  glm.CL.gr.mw.ab <- glm (dep ~ graz + mown + aban + tmpr + precip + rad + g + Shannon + hab
+ cover, data = env, family = quasipoisson)
  glm.CL.gr.mw.ab.ms <- glm (dep ~ graz + mown + aban + mosa + tmpr + precip + rad + g +
Shannon + hab + cover, data = env, family = quasipoisson)

  gr.gross.adjD2 <- adjD2 (glm.CL.gr)$adjD2 - adjD2 (glm.CL)$adjD2
  gr.net.adjD2 <- adjD2 (glm.CL.gr.mw.ab.ms)$adjD2 - adjD2 (glm.CL.mw.ab.ms)$adjD2
  gr.gross.P <- anova (glm.CL, glm.CL.gr, test = 'Chi')$Pr[2]
  gr.net.P <- anova (glm.CL.mw.ab.ms, glm.CL.gr.mw.ab.ms, test = 'Chi')$Pr[2]

  mw.gross.adjD2 <- adjD2 (glm.CL.mw)$adjD2 - adjD2 (glm.CL)$adjD2
  mw.net.adjD2 <- adjD2 (glm.CL.gr.mw.ab.ms)$adjD2 - adjD2 (glm.CL.gr.ab.ms)$adjD2
  mw.gross.P <- anova (glm.CL, glm.CL.mw, test = 'Chi')$Pr[2]
  mw.net.P <- anova (glm.CL.gr.ab.ms, glm.CL.gr.mw.ab.ms, test = 'Chi')$Pr[2]

  ab.gross.adjD2 <- adjD2 (glm.CL.ab)$adjD2 - adjD2 (glm.CL)$adjD2
  ab.net.adjD2 <- adjD2 (glm.CL.gr.mw.ab.ms)$adjD2 - adjD2 (glm.CL.gr.mw.ms)$adjD2
  ab.gross.P <- anova (glm.CL, glm.CL.ab, test = 'Chi')$Pr[2]
  ab.net.P <- anova (glm.CL.gr.mw.ms, glm.CL.gr.mw.ab.ms, test = 'Chi')$Pr[2]

  ms.gross.adjD2 <- adjD2 (glm.CL.ms)$adjD2 - adjD2 (glm.CL)$adjD2
  ms.net.adjD2 <- adjD2 (glm.CL.gr.mw.ab.ms)$adjD2 - adjD2 (glm.CL.gr.mw.ab)$adjD2
  ms.gross.P <- anova (glm.CL, glm.CL.ms, test = 'Chi')$Pr[2]
  ms.net.P <- anova (glm.CL.gr.mw.ab, glm.CL.gr.mw.ab.ms, test = 'Chi')$Pr[2]

  # regression coefficients
  gr.mw.ab.mo.net.r <- summary (glm (dep ~ graz + mown + aban + mosa + tmpr + precip + rad + g
+ Shannon + hab + cover, data = env, family = quasipoisson))$coefficients[2:5,1]
  gr.net.r <- gr.mw.ab.mo.net.r['graz']
  mw.net.r <- gr.mw.ab.mo.net.r['mown']
  ab.net.r <- gr.mw.ab.mo.net.r['aban']
  ms.net.r <- gr.mw.ab.mo.net.r['mosa']
```

```
  gr.gross.r <- summary (glm (dep ~ graz + tmpr + precip + rad + g + Shannon + hab + cover, data =
env, family = quasipoisson))$coefficients[2,1]
  mw.gross.r <- summary (glm (dep ~ mown + tmpr + precip + rad + g + Shannon + hab + cover,
data = env, family = quasipoisson))$coefficients[2,1]
  ab.gross.r <- summary (glm (dep ~ aban + tmpr + precip + rad + g + Shannon + hab + cover, data
= env, family = quasipoisson))$coefficients[2,1]
  ms.gross.r <- summary (glm (dep ~ mosa + tmpr + precip + rad + g + Shannon + hab + cover, data
= env, family = quasipoisson))$coefficients[2,1]


  res.r.adjD2.P <- c(gr.gross.r, gr.gross.adjD2, gr.gross.P, gr.net.r, gr.net.adjD2, gr.net.P,
                mw.gross.r, mw.gross.adjD2, mw.gross.P, mw.net.r, mw.net.adjD2, mw.net.P,
                ab.gross.r, ab.gross.adjD2, ab.gross.P, ab.net.r, ab.net.adjD2, ab.net.P,
                ms.gross.r, ms.gross.adjD2, ms.gross.P, ms.net.r, ms.net.adjD2, ms.net.P
  )
  res.r.adjD2.Pstar <- c(gr.gross.r, gr.gross.adjD2, signif.stars (gr.gross.P), gr.net.r, gr.net.adjD2,
signif.stars (gr.net.P),
                    mw.gross.r, mw.gross.adjD2, signif.stars (mw.gross.P), mw.net.r, mw.net.adjD2,
signif.stars (mw.net.P),
                    ab.gross.r, ab.gross.adjD2, signif.stars (ab.gross.P), ab.net.r, ab.net.adjD2,
signif.stars (ab.net.P),
                    ms.gross.r, ms.gross.adjD2, signif.stars (ms.gross.P), ms.net.r, ms.net.adjD2,
signif.stars (ms.net.P)
  )


  list (res.r.adjD2.P = res.r.adjD2.P, res.r.adjD2.Pstar = res.r.adjD2.Pstar)
}

#### The calculation ----
### Variance partitioning loop ----
res <- apply (spe, 2, FUN = function (dep) glm.varpart (dep = dep, env = env))
res.matrix <- do.call ('rbind.data.frame', lapply (res, FUN = function (x) x$adjD2))
write.table (res.matrix, file = "res.matrix.txt", sep = "\t", col.names = NA)
res.matrix.sign.abc <- do.call ('rbind.data.frame', lapply (res, FUN = function (x) x$P))
res.matrix.sign.abc.stars <- do.call ('rbind.data.frame', lapply (res, FUN = function (x) x$P.star))
write.table (res.matrix.sign.abc, file = "res.matrix.sign.abc.txt", sep = "\t", col.names = NA)
write.table (res.matrix.sign.abc.stars, file = "res.matrix.sign.abc.stars.txt", sep = "\t", col.names =
NA)


### Effect of individual management types (regression coef. + full/partial adjD2 + significance of
D2) ----
expldev <- lapply (names (spe), FUN = function (dep) expldev.multireg (spe[,dep], env))
names (expldev) <- names (spe)

# exports the results with Pstars
expldev.tab.Pstar <- t(do.call ('cbind.data.frame', lapply (expldev, FUN = function (x)
x$res.r.adjD2.Pstar)))
colnames (expldev.tab.Pstar) <- c("gr.gross.r", "gr.gross.adjD2", "gr.gross.P", "gr.net.r",
"gr.net.adjD2", "gr.net.P",
```

```
                "mw.gross.r", "mw.gross.adjD2", "mw.gross.P", "mw.net.r", "mw.net.adjD2",
"mw.net.P",
                "ab.gross.r", "ab.gross.adjD2", "ab.gross.P", "ab.net.r", "ab.net.adjD2", "ab.net.P",
                "ms.gross.r", "ms.gross.adjD2", "ms.gross.P", "ms.net.r", "ms.net.adjD2",
"ms.net.P")

write.table (expldev.tab.Pstar, file = 'expldev.tab.Pstar.txt', sep = '\t', col.names = NA)


# exports the results with full P values
expldev.tab.P <- t(do.call ('cbind.data.frame', lapply (expldev, FUN = function (x)
x$res.r.adjD2.P)))
colnames (expldev.tab.P) <- c("gr.gross.r", "gr.gross.adjD2", "gr.gross.P", "gr.net.r",
"gr.net.adjD2", "gr.net.P",
                "mw.gross.r", "mw.gross.adjD2", "mw.gross.P", "mw.net.r", "mw.net.adjD2",
"mw.net.P",
                "ab.gross.r", "ab.gross.adjD2", "ab.gross.P", "ab.net.r", "ab.net.adjD2",
"ab.net.P",
                "ms.gross.r", "ms.gross.adjD2", "ms.gross.P", "ms.net.r", "ms.net.adjD2",
"ms.net.P")

write.table (expldev.tab.P, file = 'expldev.tab.P.txt', sep = '\t', col.names = NA)
```

Table S6 Plant dataset. Species abundances were expressed on an ordinal scale as follow: 1 – sporadic; 2 – rare, covering up to 5% of the plot; 3 – scattered, 5–15% of the plot; 4 – common, 15–25% of the plot; 5 – dominant or subdominant, over 25% of the plot.

ID site			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Species	**Open-country (O) /Woodland (W)**	**Regionally Important Species**	Starohrozenkovský lom	Kladná	U Petrůvky	Štítná – stráň nad dráhou	Ploščiny	Záhumenice	Bylnice – Na stráži	Suchov – nad Ostrožankou	Nová hora	Bílé potoky	Podhradské louky	Mechnáčky	Cestiska	Kaňoury	Javorník – pod Hradiskem	Žerotín	Hutě	V Krátkých	Kútky	U Megovky	Podlučí	Končiny	Drahy	Machová	Rybnické údolí pod Machovou	Přední louky	Dolnoněmčanské louky	Paseky u Nedašovy Lhoty	Sidonie – pastvina na hranici	Javorina	Jamy u Březové	Lopenické sedlo	Skleněný vrch	Hrnčárky
Abies alba	W						1																													
Acer campestre	W			2	2	2	1		2			2		2			2	2		1	2		2		2	2	2	2	2	2					2
Acer platanoides	W																											2							
Acer pseudoplatanus	W				2					2				2	2	1			2	2			2		2	2	2		2	2	2	2		1		
Achillea millefolium agg.	O		3	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	2	2	2
Acinos arvensis	O	1				4			2									1							1											
Actaea spicata	W																																		1	
Aegopodium podagraria	O				2	2	2		2				1		2	2	3		2	2		1					2	2		2					2	
Agrimonia eupatoria	O			3	2	4			2	2	2	2			2		2	2	2		1		2		2			2		3					2	2
Agrostis capillaris (incl. *A. vinealis*)	O			2	4	3	4	2	2	2	3	2	3	3	2	3	2		2	2	3	2		3	2	2	3	2	3	3	2	4	3	2		3
Agrostis stolonifera	O																				1		1			1	2		3					2		2
Ajuga genevensis	O	1				1	2				1			1											1											
Ajuga reptans	O				2		2	2		1	2	2		2		2	2		2		2	2	2	2	2	2	2	1	2			2		2	2	2
Alchemilla sp.	O				2	2	2	3		2	2	3	2		2	3			3	2		2		2	2			2	2	2	2	2	2	2		2
Alisma plantago-aquatica	O																															1			
Alliaria petiolata	W				2								1							1	1				1										
Allium carinatum	O	1													1		2	1			1		2			1	1	2	2						
Allium oleraceum	O																			2							1								
Allium scorodoprasum	O				2	2		2	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	3	2	3	2		2		2	2
Allium ursinum	W																																		1	
Allium vineale	O															1	2						2				1									
Alnus glutinosa	W																		2					1	2					2					2
Alnus incana	W														2										2											
Alopecurus pratensis	O				5			2		2		2	2				2		2		2			2	2	2	2	2	2					2	2

Amaranthus retroflexus	O																						1													
Anacamptis pyramidalis	O	1																					2				1									
Anagallis arvensis	O			2							1						1						1							1						
Anemone sylvestris	O	1																2																		
Angelica sylvestris	O										1	1			1				2			2		1	1		2				2					2
Antennaria dioica	O	1													3	1									2											
Anthericum ramosum	O	1													2	3		2			1	2	2		2	2	1	2	2							
Anthoxanthum odoratum	O			2	2	2	2	3	2		3	2	2	3	2	3	2		3	3	3	2	2	3	2	2	2	2	2		2	2	2	2	2	2
Anthriscus nitidus	W				2																															
Anthriscus sylvestris	O				2	1		2		2	3	1	2	3		2	2	2	2	2		2	2	2	2	2	2	3		2	2	1		2	2	2
Anthyllis vulneraria	O		2			2	2		2		2	2			2	2		2	3	2	1	2	2	2	2	2	2	2		3			3	2		1
Aquilegia vulgaris	O	1										2				2	1		3			2					1		2	2					2	
Arabidopsis thaliana	O			1			2																													
Arabis hirsuta	O					2	2		1		1		2	1		2		2				2	1	1	2	2		2	2	2				2	2	1
Arctium sp.	O					1		1		2		2	1							1					2	1		2	1						1	1
Arenaria serpyllifolia agg.	O		2						2					1				1								2	1	2	3						2	
Arrhenatherum elatius	O		2		5	3	4	4	5	3	4	3	4	4	2	3	3	2	3	3	2	2	3	3	2	3	3	3		4	3	1	3	2	3	2
Artemisia pontica	O	1																1																		
Artemisia vulgaris	O		2			2				2							2	1					1		1			2								1
Arum cylindraceum	W																																			1
Asarum europaeum	W											1			1	1	2		2			2	2					1	1	1						2
Asperula cynanchica	O	1							2		2				2	2		2				2	2	1	2			2		2					1	
Asperula tinctoria	O	1								4			2				2	2			2	2	2	2	2	2	3	2	2							
Aster amellus	O	1																2																		
Astragalus cicer	O							1						2		3	2					2	2	1	2		1	2							1	2
Astragalus danicus	O	1								3			2	1	2		2	2			2		3	2	2	2	1	2	2						2	
Astragalus glycyphyllos	O		2		2	3	2		2		2	2		2		1	2	2				2	2	2	2		2	2		3	2		2		2	2
Astrantia major	O							2					1			2			2	2		2		2		2	2	2	2			2		2	2	
Athyrium filix-femina	W						1					1							1											2		2				
Atriplex patula	O																											1								
Atropa bella-dona	W						2				1	1																								1
Avenella flexuosa	O																															5				
Avenula pubescens	O							3	2	2	3		2	2		2	2	2	2		3		2	2	2	2	2	2	2		1	1			2	2
Barbarea vulgaris	O											1																								
Bellis perennis	O																					1			1									2		
Betonica officinalis	O		2	2		2	2	3	2	1	3	3	3	3	2	3	2	2	2	2	2	2	3	3	2	3	3	3	3				3		2	2
Betula pendula	W		2		2		2					2			2		2		2	2		2							2		2					2

Blysmus compressus	O	1																						1															1
Brachypodium pinnatum	O		3	3		5	5	3	5	5	3	4	4	3	3	4	5	4	4	3	4	4	3	5	3	5	5	4	3	5			4	2	3	4
Brachypodium sylvaticum	W										2			1					2				1		1										2	2
Briza media	O		2	2	2	3	2	3	2	2	3	3	2	3	2	3	2	2	2	3	2	2	2	2	3	2		2	2	4	2	1	3		2	2
Bromus commutatus	O																				2							2								
Bromus erectus	O							4	2	2	4		3	4	4	4	3	4	3		4	5	5	5	5	5	3	5	4	5					5	5
Bromus hordeaceus	O								1				1																1							
Bromus inermis	O																	2					1			2		2								
Buglossoides purpurocaerulea	W	1																2																	2	
Bupleurum falcatum	O									2	1			3	2			2				2	2	3	2	2		2	2							3
Calamagrostis arundinacea	O									1			5			2					2			2		3	2	2	2							
Calamagrostis epigejos	O		3	2		2	4		2	2	2	2	2	2	2		3	2	2	2	2	2	2	2	2	2	2	2	2	3	5	2	3	2	2	2
Calluna vulgaris	O	1																		2										1						
Caltha palustris	O																		2	2													2		
Campanula glomerata	O						3	2	2	2	3	2	2	3	2	3	2	2	3	3	2	2	2	2	2	2	3	2	2	2		1	3		2	2
Campanula patula	O			2	2	2	2	3	2	2	2	2	2	3		2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Campanula persicifolia	O		2			2	2	2	2		2	2	2	2		3	2	2			2		2	2	2	2	2	2	2				2		2	
Campanula rapunculoides	O		3	2	2	2		1	2								2	2			1			1		2	2		2	2				2	2	2
Campanula trachelium	W																2	2	2				2		2			1								1
Capsella bursa-pastoris	O						1		2	1																		1						1	
Cardamine amara	W																																2			
Cardamine impatiens	W				2																			1						1					
Cardamine matthioli	O																														1					
Carduus acanthoides	O			2		1			2	1								1						2					2							
Carduus crispus	O									2														1		1	2							1	1
Carex caryophyllea	O			2			2	2	2		2	1	2	2	2	2		2	2		2	2	2	2	2	2	2	2	2	2				2		1	2
Carex davalliana	O	1																															1			
Carex digitata	W																																		1	
Carex distans	O	1												1							2	2											1			2
Carex flacca	O		3				2	2	2	2	3	2		2	2	2	3		2	2	3	3	3	2	3	2	2	2	2	3	2		4	2		2
Carex flava	O	1																	2	2	1	2		2		1	1						1	2		2
Carex hirta	O		3		2	2	2		2		2	2		2						2	2	2		2	2	2			2		2		3	2		2
Carex leporina	O																														2		2			
Carex michelii	O	1																2					2			2	1							1		
Carex montana	O						1	2			3		2	3	3	4	3	4	3		4	4		3	3	4	5	3	5					2	3
Carex muricata agg.	O		1	2					1					1				2					2			1				2	2				
Carex oederi	O	1																				1														

Carex ornithopoda	O	1									2					2																				
Carex otrubae	O										2			1							2															
Carex pallescens	O			2	2		2	2	2			2		3		2	2		2	2	2	2	2	2			2		2	2	2	2	2	2		2
Carex panicea	O														2				2	2	2	2		2	2		1		2				1			2
Carex paniculata	O	1																	2	2				1										2		2
Carex pilosa	W																		2			1														
Carex pilulifera	O	1																													2	2				
Carex praecox	O	1																2																		
Carex sylvatica	W										2	1		2					2	1				1					1	2	1			2		2
Carex tomentosa	O		3			3			3	2	3	2		2	2	2	5	1	2	2	3	2	2	3	2	2	3	2	2	3						2
Carlina acaulis subsp. *acaulis*	O				2		2	2	2	2		2	2	2	2	2	2		2	2		2	1	2	2	2	2		2	2	2	2	2		2	2
Carlina vulgaris agg.	O		2								1						2								2								2			
Carpinus betulus	W		2		2		2	2			2	2	2			2	2		2	1	1	2	2		2	2	2	2	2	2	2				2	2
Carum carvi	O			2				2			1					2			2	2		2							2			1	2	2		1
Centaurea jacea agg.	O		3	2	2	2	2	4	2	3	3	3	3	3	2	3	2	1	3	3	2	3	3	3	2	3	2	3	3	3	2		3		2	2
Centaurea scabiosa	O		3			2	2		2			2	2				2	2	2	2		2	3	4	2	3	3		2	3			2		3	2
Centaurea stenolepis	O	1															2			2				4		3		2	2					2		
Centaurea triumfettii	O	1																2																		
Centaurium erythraea	O			1		1			1								1				1		2		1			2		2			1		2	
Centaurium pulchellum	O	1																															1			
Cephalanthera damasonium	W																	1																		
Cerastium arvense	O																	2																		
Cerastium holosteoides	O			2			2	2	2	2	2		2	2	2	2		2	2		2		2	2	2	2	2	2	2	3		1	2	2	2	
Cerinthe minor	O	1																1																		
Chaerophyllum aromaticum	O				3	2					2	2			2	2	2		2	1				2	1	1		2	2	2				2	1	2
Chaerophyllum bulbosum	O					1												1																	2	
Chamaecytisus virescens	O	1						2		2	2		2	2	2		1	2		2	2	2	3	2	2	2	2	2	2				2		2	
Chenopodium album agg.	O								1	1																				1					1	
Chrysosplenium alternifolium	W																																	2		
Cichorium intybus	O		3						2	1													2		1			2		2			2			
Circaea lutetiana	W											1	1																						1	
Cirsium acaulon	O	1								1					3	1																				
Cirsium arvense	O		2		2	2	2	2	2	2	2	2	2	2	1	2	2		2	2	2	2	2	2	2	2	2	2	2	1	2		2	2	1	2
Cirsium canum	O				2			1	2					3			2		2		2	2		2	2		2	2					1		1	2
Cirsium eriophorum	O	1					2								1														1		2					
Cirsium oleraceum	O				2	1									1				2	2				1			2		1					2		2
Cirsium palustre	O			1	1		2	1			2	2							2	1		2		1												2

Cirsium pannonicum	O						2	3		2	3	3	3	4	2	3	2		2		2	4	3	4	2	3	3	2	3	2			2		2	3
Cirsium rivulare	O	1																	2	2		2		2			1									2
Cirsium vulgare	O		2			1			1	2	1			1			2						1		2			2					2		1	2
Clematis recta	O	1											2				1	2			1		2			2	2	2	1							
Clematis vitalba	W		2			2				2	2				2		3	2					2		2			1		2			2		2	2
Clinopodium vulgare	O		2			3	2			1	1				1	2				2						1				3	2				2	1
Colchicum autumnale	O				2	2	2	3	2	2	4	3	2	3	2	3	2		4	2	3	2	2	2	3	2	2	3	2	3	2	1			2	2
Convallaria majalis	W												2										2			2	2		2						2	
Convolvulus arvensis	O			2	2	2	2		2	2			2	2	2		2			2		2	2	2	2	2	2	2		3			2		2	2
Conyza canadensis	O									1															1											
Cornus mas	W	1											1																							
Cornus sanguinea	W			2	2	4			2		2		2		2		2	2	2		2	2	3	1	2	2	2	2	2	3			3		2	2
Corylus avellana	W					2	2	2	1				2			2	2	2		1	2	2			1	2	2	2	2	2						2
Crataegus sp.	W			2	2	2	2	2	2	3	2	2	2	2	2	2	4	2	2	2	2	2	3	2	2	2	2	3	2	2	2			2	2	2
Crepis biennis	O			2	2	2	2	2	2	2	3	2	2	3	2		2	1	2	2		2	2	2	2	2	2	2	2	3			2	2	2	2
Crepis mollis subsp. *succisifolia*	O	1																																1		
Crepis paludosa	O																			2																2
Crepis praemorsa	O	1					1	1		2	1							2	2		2	2			1	2		1	2						1	
Cruciata verna	O				2	2	2	2		2	2	2	2	2	1	3	2		3	2	2	3		2	2	2	2	2	2		2	2	2	2	2	2
Cuscuta epithymum	O									2			2									1	1	2		2	2	2								1
Cynosurus cristatus	O			3	2	2		2				2	2	2		2			2	2	3	2		2	2			2	2	3	2		3	4		2
Cytisus nigricans	O	1							2									2										1	2							
Dactylis glomerata	O		2	2	3	2	2	3	2	2		3	3	3	2	3	3	2	3	2	2	3	3	2	3	2	2	3	2	3		2	3	4	2	2
Dactylorhiza fuchsii subsp. *fuchsii* var. *fuchsii*	O	1																														1				
Dactylorhiza incarnata subsp. *incarnata*	O	1																			1															1
Dactylorhiza majalis subsp. *majalis*	O	1						1				1							2	1				1												
Dactylorhiza sambucina	O	1																	2										1							
Danthonia alpina	O	1																								2										
Danthonia decumbens	O	1		2		1	2			1	2	2		3	4	3			2	2	2	2		2	2		2	1	2		2	1	3			2
Daphne mezereum	W																												1							
Daucus carota	O		2	2	2	2		2	2	2	2	2		2	2	2	2	1	2	2			2	1	2			2		3	2		2		2	2
Dentaria bulbifera	W							1				1																	1							
Deschampsia cespitosa	O													2					2		2	2		1	2		2	1	2				2	2		2
Dianthus carthusianorum	O		2				2		2		2		2	2		2	2	2			2		2	2		2	2	2		2		1			2	1
Dianthus deltoides	O	1		2							2					1																				1
Digitalis grandiflora	O	1																				1														

Dipsacus fullonum	O																																			1
Dipsacus laciniatus	O																								1											
Dorycnium pentaphyllum agg.	O			2						1	3		1	2	2		1	2		2	2	2	2	2	3	2		2	2	3			3		1	2
Dryopteris carthusiana	W																		1																	
Dryopteris filix-mas	W																													1	1			2		
Echium vulgare	O		2			2			2						1							1			2					3						
Eleocharis uniglumis	O	1																			1															
Elymus hispidus	O	1											2					2						2		3	3	2	2							
Elymus repens	O			1	3						2				1		2	2		2		2	1	1	2		1	2		2				2	2	
Epilobium dodonaei	O		1																																	
Epilobium montanum	W		1											1																				2		
Epilobium parviflorum	O																				1			1					1							1
Epilobium tetragonum	O									1																										
Epipactis helleborine agg.	W														1															1					2	
Epipactis palustris	O	1																				2														2
Equisetum arvense	O				2			2			2	2		2		2			2	2	2	2		2	2		2	2			2		2	2	2	2
Equisetum palustre	O																		2	2		2		2			1						1			2
Equisetum telmateia	O				2							2							2											2			2			2
Erigeron acris agg.	O	1								1					1								2		1											
Erigeron annuus	O																			2				1											1	
Eriophorum angustifolium	O	1																	1	2	1	3		2			1						1	2		2
Eriophorum latifolium	O	1																		2		2		2												2
Eryngium campestre	O			2					2	1					2										2											
Euonymus europaeus	W												1				2	2					2													
Euonymus verrucosus	W	1																2																		
Eupatorium cannabinum	O						2			1	2	1		2	2		1		2	2	1	2	1	2	1				2		1				2	2
Euphorbia amygdaloides	W				1														1																	
Euphorbia cyparissias	O			2	3	4	3		3	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2		2		2	2
Euphorbia esula	O		2						2	2				2			2	1	1	2			2		1			2							2	2
Euphorbia helioscopia	O																											1								
Euphorbia platyphyllos	O																											1								
Euphorbia virgata	O	1						1		2				1		1	2	2			1		2		1	1									2	
Euphrasia officinalis subsp. *rostkoviana* var. *rostkoviana*	O	1										2								2																
Fagus sylvatica	W						2								1	2			2	1			1			2	2			2						2
Falcaria vulgaris	O																	2					2													
Festuca arundinacea	O									5																										

Festuca filiformis	O	1					1														2								2		1	3				
Festuca heterophylla	O	1																2			2					2			2							
Festuca pratensis	O		3	2	3	2	2	4	2	3	2	2	3	3	2	3	2	2	3	2	3	2	3	3	2	3	3	3	3		2		3	3	2	3
Festuca rubra	O		2	5	5	4	5	4	5	3	3	4	4	4	2	4	4	2	4	2	2	2	2	3	3	3	3	3	3	2	3	3	3	4	2	2
Festuca rupicola	O		3	2	2	2		2	3	2	2	3	2	2	3	2	2	3	3	2	2	2	4	2	4	3	3	3	3	3	3		3	2	2	3
Filipendula ulmaria	O				2															3	1												1			
Filipendula vulgaris	O			2			2	3	2	2	4	3	4	4	3	3	2	2	4	2	2	4	2	3	2	3	3	3	3				3	2	2	2
Fragaria moschata	W					2	4				1	2	2		2	2	2	2	2		1	2				2	2	2	2	3	3					2
Fragaria vesca	O		2				2	2			2	2	2	2	2		3		2	2				2			2			2		2	2	2	2	2
Fragaria viridis	O		2	4	2	4	2		4	3	2	2		3	2	2		3	3		3		2	2	3	2	2	2	2	2					2	
Frangula alnus	W					2			2						2		2			2			2					2	1							2
Fraxinus excelsior	W			2						2			1	2	2	2	2	2	2	2		2	2	2	2	2	2	1	2	3	2	2	3		2	2
Galeobdolon luteum agg.	W																													2						
Galeopsis pubescens	W			2	2	1																								1	1					
Galeopsis tetrahit agg.	W																			1						1										
Galium album subsp. *album*	O		3	2	2	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	1	2	2	1	2	2	2	2
Galium aparine	W				2	1		1	2	1			1	1					2		1	1		1	1	2	2			1					2	1
Galium boreale	O	1						2		2			2				2				2		2			2	2	2	2							
Galium glaucum	O	1																2																		
Galium intermedium	W											1																		2						
Galium odoratum	W							1		1								1					2			2	2		1						2	1
Galium palustre agg.	O													2																						
Galium pumilum	O			2				2		2	2		2	2	2				2		2	2		2	2							2			2	2
Galium sylvaticum	W															1																				
Galium verum	O			2	2	2	2	3	3	3	2	2	2	3	2	3	2	2	3		2	3	3	2	2	3	2	3	3	2	2		3		2	2
Genista germanica	O	1												1	2																					
Genista tinctoria	O		2				2	3	2	2	2	2	2	3	2	3	2	2		2	2	2	2	3	2	2	2	2	3	2			2			
Gentiana cruciata	O	1													2		2						1					1								1
Geranium columbinum	O	1	2	3		1			2																					2						
Geranium palustre	O	1																		2																
Geranium pratense	O				3					2					2	1												2			1				2	
Geranium pusillum	O								2																											
Geranium robertianum	W										1								1						1			1		2					1	1
Geranium sanguineum	O	1											5			4		3			2	1		2		4	2	3	3							
Geranium sylvaticum	O	1																														2				
Geum urbanum	O			2	2	2		1	2				1			1		2	2		2		2		1	2	2	1	1	2					1	2
Gladiolus imbricatus	O	1																		2	1						2	2	2							

Glechoma hederacea	O			2			1	2	2	2	2		2				2			2		1	2		2		2	2		1				2	2	2
Globularia bisnagarica	O	1																							3											
Glyceria nemoralis	W	1												1																				2		
Gnaphalium sylvaticum	O						1																													
Gymnadenia conopsea	O	1										1		1	3	1	1		2			2	2	2	2	1			2			1			1	
Gymnadenia densiflora	O	1													2					1				2												2
Helianthemum grandiflorum subsp. *obscurum*	O			2		2	2	2	2		2	2	2	2	2	2		2	2		2	2		2	2	2	2	2	2	3	1				2	2
Helictochloa pratensis	O	1																1								1										
Heracleum sphondylium	O				2	1		2		2	2	2			2	2	2	2	2	2		2	2	2	2	2	2	2	2	2		2	3	2	2	2
Hieracium lachenalii	W		2	1		2		1				2			2				1		1			1					1			3				
Hieracium murorum	W		2				2								2														2	1		2				
Hieracium sabaudum	W		2			2									1								1						2						2	
Hieracium umbellatum	O	1											2					2								2	1									
Hippocrepis comosa	O	1														1														2						2
Holcus lanatus	O			2	2	1	2	3		2	3	2	2	3			2		2	5	4	2	2	3	2		3	3	2	3	2	1		2	3	2
Hordeum vulgare	O																											1								
Hylotelephium maximum	O																	1																		
Hypericum hirsutum	O										1						2					1	1													2
Hypericum maculatum	O				2			2					2			2			3	2		2		2		2	2	1	2			4		3		
Hypericum perforatum	O				2	2	2	2	2	2	2	2	2	2	2	3	2	2	1	2	2		2	2	2	2	2	2	2	3			2		2	2
Hypericum tetrapterum	O																							1									1			1
Hypochaeris maculata	O	1						2				1		2		3		2		2		3		2		2	2	2	3			2				
Hypochaeris radicata	O	1		2	2		2					1								2		1									2		2	1		
Impatiens noli-tangere	W																		1						1		1					1				
Impatiens parviflora	W		2	1	2															2					1										1	
Inula britannica	O								2																											
Inula ensifolia	O	1													1			2					2													
Inula hirta	O	1											1			3		2						1		3		2	2							
Inula salicina	O								2	2	2	3	2	3	2	2	4	1	2		2	3	2	2	2	3	3	3	4				3		2	
Iris graminea	O	1														1										2			1							
Iris variegata	O	1																2					1			2										
Juglans regia	W				2				2								2						2		1					2					1	1
Juncus articulatus	O		2											1						2	2	2		2		1	2		1					2		2
Juncus compressus	O																			2	1															
Juncus conglomeratus	O																				1															
Juncus effusus	O											2																						2		

Juncus inflexus	O		2					1						2					2	2	2	2		2		2	2		2					2		2
Juniperus communis subsp. *communis*	W	1					2								2										2											
Klasea lycopifolia	O	1											2																							
Knautia arvensis agg.	O		2		2	2	2	3	3		3	2	3	4	2	3	2	2	3	2	2	3	3	2	2	3	2	2	2	4			2	2	2	3
Koeleria macrantha	O	1							2									2								2										
Koeleria pyramidata	O		2				2			2	2	2	2	1	3	2	2		2	2		2	2	2	2	2	2	2	2			2	3			2
Lactuca serriola	O																																		1	
Lamium maculatum	W																																		1	1
Lamium purpureum	O																						1													
Lapsana communis	O			2					2																		1			2	1				1	
Larix decidua	W									2							2					2		1												
Laserpitium latifolium	O	1						2								2								2		3	2	1	2							
Laserpitium prutenicum	O	1											1											2					2							
Lathyrus latifolius	O							2		2			2	2			2	2	2		2	2	2	2	2	2	2	2	2				2		2	2
Lathyrus niger	O							2				2	2	2		2				2	2			2	2	2	2	2	2	2			2			
Lathyrus pannonicus subsp. *pannonicus*	O	1						1			1			1																						1
Lathyrus pratensis	O		3	2	2		1	4	2	3	2	2	2	2		2	3	2	3	2	2	1		2	2	2	2	2	2	3	2			2	2	2
Lathyrus tuberosus	O			2	2				2	2	2						2	1		2			2					2		2					1	2
Leontodon hispidus	O			2	2	2	2	4	2	2	2	4	2	3	2	3	2	1	4	2	2	3	3	2	2	3	3	2	3		2		4	2	2	2
Lepidium campestre	O																											1								
Leucanthemum vulgare agg.	O		3		2	2	2	3	2	3	3	2	2	4	3	3	2	2	3	2	2	2	2	3	3	2	2	2	2	2	2	2	4	2	2	2
Libanotis pyrenaica	O	1																2																		
Ligustrum vulgare	W		2		2	2	2	2	2	2	2	1	2		2	2	3	2	2	1			2	2	2	2	2	2	2	2					2	2
Lilium martagon	O	1			1			1					1			2										1	1	2	2			1			1	
Linaria vulgaris	O					1			2	1													2					1								
Linum catharticum	O		2	2	2	2			2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	3	2				2	2
Linum flavum	O	1							1									2								1										
Listera ovata	O				1	1		1		1		2			2	1	2		3	1	1	2	1	2	2	1	1		2						2	2
Lolium perenne	O			3					2									1					2	1			1	2					3	2		
Lonicera xylosteum	W																								1											
Loranthus europaeus	W																	2			2															
Lotus corniculatus	O		3	2	2	2	2	4	3	2	4	2	2	3	2	3	2	2	3	2	2	2	2	2	2	2	2	3	2	3	2	1	3	2	3	2
Lotus maritimus	O	1								1					2					2			2													
Luzula campestris agg.	O		2	2	2		2	2	2		2	2	2	2		3	2	2	2	2	2		1	2	2	2	2	2	2	1	2	2			2	
Luzula luzuloides	O																										1				1	3		2		
Lychnis flos-cuculi	O											1	1						2	2	2							1						2		

Lycopus europaeus	O													1					2		1	2									2					2
Lysimachia nummularia	O			2	2			2	2		2	2	2	2			2		2	2	2	2		2	2	2		2		2	2				2	2
Lysimachia vulgaris	O											1							2	2	2	2				1	2	1	1		2			2		2
Lythrum salicaria	O		2																		2	2		1			2	1								2
Malus sylvestris agg.	W				2	2		2	2			2					2		1			1					2			2	1			1		2
Malva neglecta	O			1																																
Medicago ×varia	O																1																			
Medicago falcata	O					2		4	4	2	4	2	2	2	2	2	2	3	2		1	2	3	3	2	2	2	3	2	2			3		2	2
Medicago lupulina	O			2	2	2		2	2		2	2					2	1	2	2	1		2	2	2			2		3	2				2	2
Melampyrum arvense	O	1				2			3								2						1													
Melampyrum cristatum	O	1						2				2		3				3				2		2		3			3							
Melampyrum nemorosum	O	1	4						2			2				3				2			2			2		1		2					2	
Melampyrum pratense	O	1																		2																
Melica nutans	W																		1																	1
Melica transsilvanica	O	1																1																		
Melica uniflora	W																						2												2	
Melilotus albus	O		2																																	
Melilotus officinalis	O					2			2								2	2					2	2	1			2								
Mentha longifolia	O										1			2					2	2	1	2		2	2		2			1	2		2	2		2
Mentha sp. (*M. arvensis/M. aquatica*)	O																				2															1
Milium effusum	W				1																											1				
Molinia arundinacea	O	1											2		3	2					3		2	2		2	2	2	4							
Muscari comosum	O	1							2			1					2	2					2	1		1	2			1						1
Mycelis muralis	W						2																													
Myosotis arvensis	O			2	2					2			2	1			2		2	2	2	2	2		2	2	2	2	2	2			2		2	2
Myosotis palustris subsp. *laxiflora*	O	1										2		1										1									1			2
Myosotis sylvatica	W			2	2	2	2		2																					2						
Myosoton aquaticum	O				2																															
Nardus stricta	O	1																	2			1										4				
Neottia nidus-avis	W											1																								
Nepeta nuda	O	1																								1										
Neslia paniculata	O								1																											
Odontites vernus	O			2																																
Onobrychis viciifolia agg.	O							2			2			2				2				2		2	2											2
Ononis spinosa	O			2	2	1	2	3	3	2	2	2		2	2	2	1	2	2		2	2	2	2	2	2	2	2	2	1	2		4		2	2
Onopordum acanthium	O																													1						
Ophioglossum vulgatum	O	1																				1			1						1					2

Ophrys holoserica subsp. *holubyana*	O	1									1							1				1														
Orchis mascula subsp. *speciosa*	O	1												1		1	1							1		1									1	
Orchis militaris	O	1															1		1			2	1		2											
Orchis morio	O	1										1		1													1									
Orchis ustulata	O	1									2			2								1	1	2	2			1	1							
Origanum vulgare	O	1	2	3			2		2							2	2	2					2						2	3						
Ornithogalum brevistylum	O	1																					2													
Orobanche alba subsp. *major*	O	1																										1								
Orobanche flava	O	1																		2																
Orobanche lutea	O	1							1								1	1					1	2	2		1	2	2							
Oxalis stricta	O																			2																
Paris quadrifolia	W																																			2
Pastinaca sativa	O		2						2								2						2					2							1	
Persicaria lapathifolia	O									1																										
Persicaria mitis	O			2																																
Petasites hybridus	O																			2		2		1			3									1
Peucedanum alsaticum	O	1																3																	2	
Peucedanum cervaria	O	1							3				2			2	2	4			2		2			2	2	3	3							
Phalaris arundinacea	O					2																														
Phleum phleoides	O	1							2				1					2			2					2		1								
Phleum pratense agg.	O		2	2	3		2	3		2			2			2	2			2	2		1	2		2	2	2	2	3	2	2	3	2		2
Phragmites australis	O										2			2					2		2	2											2			3
Phyteuma spicatum	O															1				1									2			1		2		
Picea abies	W		2	1	2		2			2		2							1					2					1		2			1		
Picris hieracioides	O								2	2							2	2					2		2			2								
Pilosella bauhini s. l. (*P. piloselloides* agg. incl. *P. densiflora* & *P. floribunda*)	O	1					1	2	2		2	2		2	2						2		1		2	2			1	2			2		2	1
Pilosella officinarum	O			2			2		2			1			2			1	1	2	1	2			2			1	1	2	2					
Pimpinella major	O							2			2									2														2	1	
Pimpinella saxifraga	O		2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	3			2	2	2	2	2		2	2	2	2		2	2	2	2
Pinus sylvestris	W		2			2	2					1			3							2	1		2				2	2	3		2			
Plantago lanceolata	O		3	2	2	2	2	3	2	2	3	2	3	2	2	3	2	1	4	4	2	2	3	2	3	2	2	3	3	3	2		2	3	2	2
Plantago major	O		2					2	2	2		2	2		2		2			2	2	2	2	2	2		1	2	2	1	2		3	2		2
Plantago media	O		2	2		2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2	3	2	3	2	2	2	2	2		1	3		2	2
Platanthera bifolia	O	1						1		1		1			1	1				2		1			1	1	1		2		1		1		1	
Platanthera chlorantha	O	1								1					2		1						2	1	2				1							2
Poa annua	O																											1					2			

Poa compressa	O		2	2			2				1				2						1															
Poa nemoralis	W																							1		2	1								1	
Poa pratensis agg.	O							3		3	3		3	2	2	2	2	2	2	2	2	2	3	2	3	3	2	3	3	3			2		2	2
Poa trivialis	O			2	3	2	3		3	1		2	2		1		1		2		2	2	2	1	2	2	2	2	2		2			2	2	2
Polygala amarella subsp. *amarella*	O	1													2							2		1	2				1							
Polygala comosa	O			2		2	2		2	2	2	2		1	2	3	2		2			2		1	2			2		3						2
Polygala major	O	1									3			2	2			2					2	2	2	1			2				2		2	2
Polygala vulgaris agg.	O	1			2		2					2		2	2	2			2	2		1		1					2		2		2			
Polygonatum multiflorum	W											1																							1	1
Polygonatum odoratum	O	1																2				1				2	2		1							
Polygonatum verticillatum	O																															2				
Polygonum aviculare agg.	O																						1					2		1						
Populus nigra agg.	W											2																								
Populus tremula	W		2	2									2		2	2		2	2		2	2					2		2		2					2
Potentilla alba	O	1									2	2	4		2	4	1	2		2	2			2		4	4	2	4							
Potentilla anserina	O									2							1			2				1				2	2							
Potentilla argentea	O		2				1																													
Potentilla erecta	O	1			2		2	2		2	2	2	2	2	3	2			3	2	2	2					2	2	2		2	3	2	2		2
Potentilla heptaphylla	O		2	3	2	2	2	2	2	2	2		2	3	2		2	2	3	2	2	2	2	2	2	2	2	2	2	2			3		2	2
Potentilla reptans	O		3	2	2	2		2		3	2			3	2		2		2	2	2	2	1	2	2	2	2	1	1	2	2		3			2
Primula elatior	O				2						1									2												2		2		
Primula veris	O					1	2	2	2	2	2	2	3	3	2	3	2	2	4	2	2	2	2	3	2	2	3	3	3	2					2	2
Prunella grandiflora	O	1							2				2			2		3			2	2	2	2		2	3	2	2						2	
Prunella laciniata	O			2					2		2				2			1		2	2		2		2			2		2	2		2		2	
Prunella vulgaris	O			2		2	2		2	2	2	2	2	3	2	2	2		3	2	2	2	2	2	2		2	2	2	2	2		3	2	2	2
Prunus avium	W		2	2	2		2	2		2	2		2		2	1	2		2			2	2		2	2		2		2			2	1	2	2
Prunus cerasifera	W					2																				1										
Prunus domestica	W			2		2	1		2		2	2			2	1	3		2			2	3		2					2					2	
Prunus spinosa	W				2	2	2		2	2		1	2	2		2	3	2			2		3		2	2	2	2	2	2			2			2
Pteridium aquilinum	O																													1						
Pulmonaria angustifolia	O	1											2													2										
Pulmonaria mollis	O				3	2		2								3	3	2								2		3	2						2	
Pulmonaria officinalis agg.	W			2				1				2							2			1	1		2		1	1		2						2
Pulsatilla grandis	O	1																1								1										
Pyrus communis	W							2						2			2			1																
Pyrus pyraster	W									1		2	2		2	2	2	2	1			2	2	1	2	2	1	2	2	1	2					2
Quercus petraea agg.	W		2	2	2	2	2	2	2		2	2		2	2	2			2	2	2				2	2	2		2	2	2		2		2	2

Quercus pubescens agg.	W	1															3																			
Quercus robur	W							2		2			2			2	2			2	2		2	2	2	2	2	2	3						2	2
Ranunculus acris	O		2		2	1		3		2	3		2	2			2		2		2	2	2	2	2	2	2	2	2	2	2	3	2	3		2
Ranunculus auricomus agg.	O				2	1		2					2				2		1		1					2	2		2				2			
Ranunculus bulbosus	O						1	2	2					2								1											2			
Ranunculus polyanthemos	O		2	2	2	2	2	3	2		3	2	3	3	2	2	2	2	3	2	2	2	3	2	2	2	2	2	2	3	1		2		2	2
Ranunculus repens	O		3	2							2	2	1	2					2	2	2			1	2				1	2	1					2
Rhamnus cathartica	W	1								1					1	1	2	2					2		2	2			2							2
Rhinanthus alectorolophus	O	1									2																									
Rhinanthus major	O	1										2							1				3	2												
Rhinanthus minor	O	1			2			2	2		3	2	2	2	3	3			2	4	1		2	1	3	1	2	2	2			1	2		1	2
Rorippa sylvestris	O																													1						
Rosa canina agg.	W		3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2		2	2	2	2
Rosa gallica	O	1										2	1				2				1			2				2	2							
Rubus caesius	O		3		2	2						2			2		4						2		2			2	2	2						1
Rubus idaeus	W					1	2	2	2			1	2			2	2		2	2	2	2		1	2		2		2	2	2	2				2
Rubus sp. (*R.* sect. *Corylifolii* & *R.* sect. *Rubus*)	W			2		1	2		2				2	2					2	2			2			2	2			3	2	2		2		1
Rumex acetosa	O		2	2	2	2	2	2	2	2	2	2	2	2		2	2		3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2
Rumex acetosella	O						2																											2		
Rumex arifolius	O																															1				
Rumex crispus	O				2					2	1		1				1			2	1				1			1		2				2		2
Rumex obtusifolius	O							2																		1								2		
Salix alba	W				2																		2										3			
Salix caprea	W				2										2		2		2	1				1	2	2	2	2	2		1		2			2
Salix cinerea	W													2							2						2	2					3	1		
Salix euxina	W				2																	1			1											
Salix purpurea	W																																			2
Salvia glutinosa	W						2					2				2																				
Salvia pratensis	O				2	2		2	3	2	3	3	2	3	2	3	3	2	4	2	2	2	3	2	2	2	2	2	2				3		3	2
Salvia verticillata	O					2	2		4		2	2		2		2				2		2	2		2	2	2			4	2				2	2
Sambucus nigra	W				2			1					1		1								2	1	2	2	2	1	1		1	1		1		
Sanguisorba minor	O		2	2		2	1		2	2	1	2			2	2	1			2		2	2	1	2			2		2	1		2		2	2
Sanguisorba officinalis	O				2			3				2	4		2	2			4		2		2		2	3	2	2	3			2	1	2		2
Sanicula europaea	W																						1													
Scabiosa ochroleuca	O	1								1	1							2				2	2	1	2										2	
Scirpus sylvaticus	O											2								2		2											2			2

Scorzonera hispanica	O	1											1				1					1				2	2	1								
Scorzoneroides autumnalis	O						2			1																								2		
Scrophularia nodosa	W		2		2		1			1							1			1	1					1	1	1			2				1	
Securigera varia	O		4	2		2	2		3	2	2			3	2	2	2	2	2	2	2	2	2	2	2	2	2	2		3			4		2	2
Sedum sexangulare	O	1		2												1				2										2			2		1	
Selinum carvifolia	O	1		2		2						2																								
Senecio germanicus	W									1																										
Senecio jacobaea	O			2	2	2	2		2	2			1		1	2	2						2		2			1								1
Senecio ovatus	W									1																		1	1			2				
Senecio umbrosus	O	1																							2											
Serratula tinctoria	O	1											3			2		2			2		2			3		3	2							
Seseli annuum	O	1								1					2			2					2													
Silaum silaus	O	1															1				2															
Silene dioica	O																			1												1				
Silene latifolia subsp. *alba*	O					1																														
Silene nutans	O		2										2	1		2		2	2	2	2					2		1	2			2			2	1
Silene vulgaris	O		2				1											2		2			1			2		2	2	2						
Silybum marianum	O									1																										
Sinapis arvensis	O																								1			1								
Sisymbrium officinale	O			2					2																											
Sisymbrium strictissimum	O																	1																		
Solanum dulcamara	W																												1							1
Solidago gigantea	O																																			1
Solidago virgaurea subsp. *virgaurea*	O											2	2			2	1	2				1	2		1	2			2						2	
Sonchus arvensis	O									1											1				1											1
Sonchus asper	O																						1												1	
Sonchus oleraceus	O										2			1																						
Sorbus aucuparia	W						1															1										2				
Sorbus torminalis	W	1										1																	2							
Stachys alpina	W																						1												2	2
Stachys palustris	O																1			1																
Stachys recta	O	1																2																		
Stachys sylvatica	W		2														2			1				1	1		1			2					1	1
Stellaria graminea	O		2	2	2	2	2	1	2	2		2	2	2	1	2			2	2	2		2		2	2	2	2		3	2	2	3	2	2	2
Stellaria media agg.	O		2				1		2																									2		
Succisa pratensis	O	1																		2	1							2	2							2
Symphyotrichum novi-belgii agg.	O		2																																	

Symphytum officinale	O					2				2	2						2					2		1			2	1						1	1	2
Symphytum tuberosum	O				2							2			1	2	1	2		2						2	2	1	2	2			2			
Tanacetum corymbosum	O					2		2	3				2			2	2	3			2	2		2		3	3	3	3				2		2	
Tanacetum vulgare	O		2				1																							2	2					
Taraxacum sect. *Erythrosperma*	O	1																1																		
Taraxacum sect. *Taraxacum*	O		3	1	2	2	2	3	2	3	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	2	2
Teucrium chamaedrys	O					2	2		2	2	2			2	2	2		2			2	2	2	2	2	2	2			3					2	2
Thalictrum aquilegiifolium	O	1														2																				
Thalictrum lucidum	O	1																								2	1	2	2							
Thalictrum minus	O	1																1																		
Thalictrum simplex subsp. *galioides*	O	1																									2									
Thesium linophyllon	O	1				2		2	2		2		2	3	2		1	2		2	2		2		2	2	2	2	2						2	
Thlaspi arvense	O																											1								
Thlaspi perfoliatum	O			2					2					1																2						
Thymus pulegioides	O		2	3		2	2		2	2	2	3	1	3	2	2			3	2	2	2	2		2	2	2	2		2	2	1	3			1
Tilia sp. (mostly *T. cordata*)	W					2				2			2			1	2	2					2	1		2	2	2	2	1					2	
Torilis japonica	W								1																1	1	2				2				2	
Tragopogon orientalis	O		2		2	2	1	2	2	2	2	3	3	3	2	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2		1	3		2	2
Traunsteinera globosa	O	1						1							1	1			2			1		2		1			2			1				
Trifolium alpestre	O	1						2	2		2		3	3		3		2		2	2	2		3	2	3	3	3	3				3	2	2	
Trifolium aureum	O		2																	2							1									
Trifolium campestre	O		2	2			1			3	2		2	2			2	2			2		2	2	2	2	2		2					2	2	
Trifolium dubium	O							2						2							2					2							2			
Trifolium hybridum	O		2					2		2							1				1									2			2			
Trifolium medium	O		4	2	2	3	2	4	2	2	4	3	2	4	2	2	4	2	3	2		3		3			3	2	2	2	2	1	2		2	2
Trifolium montanum	O					2	2	3	2	2	4	3	2	4	3	3	2	3	3	3	2	3	3	3	2	3	3	2	3	2			3		2	3
Trifolium ochroleucon	O			2					2	2	1									2	2			2				2		2			2			
Trifolium pratense	O		3	2	2	2	1	4	2	2	3	2	2	3	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
Trifolium repens	O		3	4	2		2	2	3	3	2		2	2	1	2		1	2	2	2		2	1	2			2	2	2	2	1	4	2	2	
Trifolium rubens	O	1						2			2		2	2	1	2	2	2			2	2	2	2	2	2	3	2	2				3			2
Triglochin palustris	O	1																																		1
Tripleurospermum inodorum	O									1																										
Trisetum flavescens	O		3	2	3	2	4	3	4	3	3	3	3	3		3	3	2	3	3	3	3	3	3	3	3	3	4	3	3	2	2	3	3	3	3
Turritis glabra	O		1						1																											
Tussilago farfara	O		3		1		1				2	2		2	2				2	2	1	2		2	2		2		1		2		2	2		2
Typha latifolia	O													2																						
Ulmus minor	W	1																2																		

Urtica dioica	O		2	2	2	2	2	2	2	2			1			1			1	2	2	1	1	1	1	1	2	2	2	2	1		2	2	1	2
Vaccinium myrtillus	O	1																														2					
Valeriana dioica	O	1																	1	2		2		2									1	2		2
Valeriana officinalis agg.	O		2			2		1	1	2	2	2	2		2	2	3	2	1	2			2	2	2	2	2	2	2	2		2				1	2
Verbascum chaixii subsp. *austriacum*	O	1																2																		2	
Verbascum nigrum	O	1																											2								
Verbascum sp. (*V. densiflorum*/*V. phlomoides*/*V. thapsus*)	O	1																										1	1								
Veronica arvensis	O			2						2	2		2			1										2	2							1	1
Veronica beccabunga	O													2									1								1	2				
Veronica chamaedrys agg.	O			2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	3	2	2	2
Veronica officinalis	O			2	2	2	3			2	2	2		2	2	2			2	2		2			2		1	2	2		3	2	2	2		2
Veronica orchidea	O	1																					2		2	2										
Veronica persica	O																										1									
Veronica serpyllifolia	O			1				1																1				2								
Veronica teucrium	O	1				2			2			2		2		2	2	2				2	2		2	2	2	2	2							
Viburnum lantana	W	1						1									2	2					2		2			2	2	1				1	1
Viburnum opulus	W				2	2		2		2	2				2	1	2	2	2	1			2		2		2	2	2		2			1		2
Vicia angustifolia	O							2		2													2					2						1		
Vicia cracca agg.	O		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	3	2	2	3	3	3	2	2			2	2	2	2
Vicia dumetorum	W																												1								
Vicia hirsuta	O							2		2			2	2									2					2						2		
Vicia sepium	O				2		2		2	2			2			2	2					2		1			2		2	2		1		2	2	
Vicia tetrasperma	O				2				2	2			2								2		1		1	1		2			2					
Vincetoxicum hirundinaria	O					3							1			2	1	2			1		3			2			2					2		
Viola arvensis	O					1				1	1																1		1				2			
Viola canina	O	1						2		1	2		2	2	2	2			2	2	2	2		2		2	2	2	2			2					
Viola hirta	O			2	2	4	2		2		2	1	2	2	2	2	2	2	3	1	2	2	2	2	2	2	2	2	2	2	2			2	2	
Viola odorata	W						2																													
Viola reichenbachiana	W				2			1			1				1				1	1		2			1	2	1						2	1	
Viola riviniana	O					2	2				1	1																	2							

Table S7 Butterfly dataset. Species abundances were expressed on an ordinal scale as follow: 1 – 1 specimen; 2 – 2–10 specimens; 3 – 11–50 specimens; 4 – 51–100 specimens; 5 – >100 specimens.

ID site			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Species	**Open-country (O) /Woodland (W)**	**Regionally Important Species**	Starohrozenkovský lom	Kladná	U Petrůvky	Štítná – stráň nad dráhou	Ploščiny	Záhumenice	Bylnice – Na stráži	Suchov – nad Ostrožankou	Nová hora	Bílé potoky	Podhradské louky	Mechnáčky	Cestiska	Kaňoury	Javorník – pod Hradiskem	Žerotín	Hutě	V Krátkých	Kútky	U Megovky	Podluči	Končiny	Drahy	Machová	Rybnické údolí pod Machovou	Přední louky	Dolnoněmčanské louky	Paseky u Nedašovy Lhoty	Sidonie – pastvina na hranici	Javorina	Jamy u Březové	Lopenické sedlo	Skleněný vrch	Hrnčárky
Adscita statices	O											2							4	1						2	2							NA	NA	NA
Aglais urticae	O						2				1	2						1								1	1	1		1	1	2	1	NA	NA	NA
Anthocharis cardamines	O		2	2	2	2	2	2		1	2	2	2	2	2	2	1	3	2		2	3	2	2	1	2	2	2	3	2	2	2	3	NA	NA	NA
Apatura ilia	W																				1								1					NA	NA	NA
Apatura iris	W		2		1							1						1										1	2			2		NA	NA	NA
Aphantopus hyperantus	O		4		3	2	3	4	3	1	4	5	3	5	5	3	3	3	3	3	4	3	4	3	1	4	4	3	4	3	5	3	3	NA	NA	NA
Araschnia levana	O		2	2	2	1	2	2		2	2	1		1	2	1	1	3	2	2	1	2	2	2		2	2	2	2	2		2	2	NA	NA	NA
Argynnis adippe	O					1	1	2			1	3	2	2		2				2	2	3	2	2		3	3	2	1	2		2	2	NA	NA	NA
Argynnis aglaja	O		1	2		1	2	4	1	2	1	3		3		2			2	1	2	1		1		4	4	2	2		1	2		NA	NA	NA
Argynnis niobe	O	1																				2												NA	NA	NA
Argynnis paphia	O		3	2	2		2	2			3	4	2	3	1	1	1	2	2	2	2	3	2		1	3	3	2	3	2	2	3	2	NA	NA	NA
Aricia agestis	O		2		2	2			2		2			1		1	2	2			3	2	2			3	3	1	1	2		3	1	NA	NA	NA
Aricia eumedon	O	1									2						1					2								2				NA	NA	NA
Boloria dia	O		2	2	2	4			3		1	2		2		2	3	2	4		2	2	4	1	1	2	2	2	2	2	3	2	1	NA	NA	NA
Boloria euphrosyne	O			1					1													2				2	2		2		2			NA	NA	NA
Boloria selene	O				2	2	2	2						3				2	4	2	1	2				4	4	1	3		3	2		NA	NA	NA
Brenthis daphne	O	1	1								2						1	2				3	3			2	2					2		NA	NA	NA
Brenthis hecate	O	1									1		2	2			2		5	2	3	2	2	1	1	5	5	3	2					NA	NA	NA
Brenthis ino	O				2			3		1	1		2		3	2	2					2	1	2	1	5	5	2	3	2			1	NA	NA	NA
Brintesia circe	O		2		2	2	2	1		1	2	2				2		2			3		2		1	1	1	2	1	2	1			NA	NA	NA
Callophrys rubi	O		2									2			2			3				2	2	2				2		1		2	2	NA	NA	NA
Carterocephalus palaemon	O		2			2		1	1	1		2	2	2	2	3		2	3	1	2	2	2	2		3	3	2	2	1	2	2		NA	NA	NA
Celastrina argiolus	O		2					1			1				1			2					2	1			1	2			2	1	NA	NA	NA
Coenonympha arcania	O				2						2				3		2	2							1			1		2	3	2		NA	NA	NA
Coenonympha glycerion	O		2		3	4	2	2	2		2	3		3	2	4	3	3	4		3	2		2	1	4	4	1	2	3	3	2	2	NA	NA	NA
Coenonympha pamphilus	O		4	2	3	3	2	3	1	1	2	2		3	1	3	2	2	4	2	4	1	2	2	1	5	5	3	2	3	3	2	2	NA	NA	NA

Colias alfacariensis	O								3									1								2	2							NA	NA	NA
Colias crocea	O					2	1	1	2		2		2			1	1	2	2		2	1				2	2	2	1	2			2	NA	NA	NA
Colias erate	O					1											1	1	2			1								1				NA	NA	NA
Colias hyale	O		3		1	3	2	2	4		2	2	1	2		2	2	2	1	1		2	2	1	1	2	2	2	2	3		2	2	NA	NA	NA
Cupido argiades	O		2	2	3	3		3	3	1	2	2		2		2	3	3	4	2		3	3		1	4	4	2	2	3	2	2	2	NA	NA	NA
Cupido decoloratus	O		1			2																	2							2				NA	NA	NA
Cupido minimus	O		2				2		1			2		2	3	2	2	2				2	2	1	1	1	1	3	2	2	1	2		NA	NA	NA
Cyaniris semiargus	O		2		2		1	1		1		2	1			2	2	2	3			4	4		1	2	2	1	2	2	2	2		NA	NA	NA
Erebia medusa	O																	2					3			3	3					3		NA	NA	NA
Erynnis tages	O		3	2	2	2	2	2	4	2	2	2	2	3	1	3	2	2	2		1	3	3	2	1	2	2	2	2	2	2	2	2	NA	NA	NA
Favonius quercus	W																	1							1									NA	NA	NA
Glaucopsyche alexis	O	1										1					1					1	2											NA	NA	NA
Gonepteryx rhamni	W		3	2	2	2	2	2	2			2				1	1	2	2	1	1	2	2	1		2	2	2	1	2	2	2	2	NA	NA	NA
Hamearis lucina	O	1																	2			2		1				1						NA	NA	NA
Hesperia comma	O				1	2		2	2		2				1	2		1	1				2			2				1		2	3	NA	NA	NA
Heteropterus morpheus	O										3						2	2				2	2					2	2			2		NA	NA	NA
Inachis io	O		2	2	1	2	2	2	2	2	2	5	2	2	2	1	2	2	2	2	2	2	1	2	1	4	4	2	2	2	2	2	2	NA	NA	NA
Iphiclides podalirius	W	1	1	1	1	1			1	2	1						2	2					1	1				1		1		1		NA	NA	NA
Issoria lathonia	O		2				2				1	1		1				2	1							1	1		2			1		NA	NA	NA
Lasiommata maera	O																	2																NA	NA	NA
Lasiommata megera	O		2				1		2									2										1		1				NA	NA	NA
Leptidea juvernica	O		3	1	3	3		2	2	3	3	2	3	3	3	3		2	2	2	2			3	1	2	2	3	2	3	3	2	2	NA	NA	NA
Leptidea sinapis	O						2				2	2		3	3	2		3				2	2		1						2	3		NA	NA	NA
Limenitis camilla	W	1					1						1																					NA	NA	NA
Lycaena alciphron	O	1			1							1								1										2	2	2		NA	NA	NA
Lycaena dispar	O	1			2		1			1	2						1	1				2	2		1	1	1			1	1		1	NA	NA	NA
Lycaena hippothoe	O						2	2			2	2		3		2	1	1	2	1		3	3		1	2	2		3	3	2	2	1	NA	NA	NA
Lycaena phlaeas	O		2			2	2	1	1		1	1			1	1		1		1	1			1		1	1	1			1	2	1	NA	NA	NA
Lycaena tityrus	O				2	1			2		2			2		2						2	3							1	2			NA	NA	NA
Lycaena virgaureae	O				3		2			1		2	2			2	1	2	3	2		4	3	1	1	4	4	2	3	3	2	3		NA	NA	NA
Maniola jurtina	O		5	2	4	3	4	5	5	3	5	5	4	5	5	4	4	3	5	5	4	4	4	5	1	5	5	5	4	4	3	3	5	NA	NA	NA
Melanargia galathea	O		5	2	3	4	3	5	4	2	5	5	2	5	5	4	3	4	4	2	5	4	4	2	1	5	5	3	4	4	4	3	3	NA	NA	NA
Melitaea athalia	O		4	2	3	3	2	2	2	1	3	4	2	2	3	3	3	1	3	4		3	4	1	1	4	4	2	3	3	2	2		NA	NA	NA
Melitaea aurelia	O	1	2			3			2		3	1			2		2	2			4		1		1			2	2	3			2	NA	NA	NA
Melitaea cinxia	O	1	4		2	3			3		2	3	1	2		2		2	3	2	2	3	3				1			3				NA	NA	NA
Melitaea didyma	O	1	2																															NA	NA	NA
Nymphalis antiopa	W						1							1		2					2	1									1	1		NA	NA	NA
Nymphalis polychloros	W															1		1			4		1						1		2			NA	NA	NA
Ochlodes sylvanus	O		2		2	2	2		2		2	3	1	2	2	3	1	2	4				2	2		3	3	2	1	2	3		2	NA	NA	NA
Papilio machaon	O			1		2	1		1	1	1	1		1	2		1	2	1				2	1	1	1	1	1	1			2	1	NA	NA	NA
Pararge aegeria	O		3		2		2	2			1	3		2	2			2	3	2	4	1	2	1		3	3		1	1	2	2	2	NA	NA	NA

Parnassius mnemosyne	O	1																								3					3		NA	NA	NA
Phengaris alcon	O	1														1								1									NA	NA	NA
Phengaris arion	O	1																												1			NA	NA	NA
Phengaris nausithous	O	1			2			3		1					1	1											2	2				1	NA	NA	NA
Phengaris teleius	O	1			1			4				3		2	4	3			3							2		3				2	NA	NA	NA
Pieris brassicae	O		3	2	1	2	2	2	2		2	3		2	2		2	2	3	2	1	2	2		1	2	2	2	2			1	2	NA	NA	NA
Pieris bryoniae	O	1										3																1			2		NA	NA	NA
Pieris napi	O		3	2	2	1	2	2		2	2	4	2	2		2	2	2	2	2	3	2	2	2	1	2	2	1	3		2	3	2	NA	NA	NA
Pieris rapae	O		4	2	3	3	2	4	2		3	3	1	3	2	2	2	3	3	2	3	2	2	2	1	4	4	2	2	3	2	2	2	NA	NA	NA
Plebejus argus	O		3	2	2	1		1	3		3				1		2	3			2	4	4		1	1	1		3	3		2	2	NA	NA	NA
Plebejus argyrognomon	O		2		3	2		1	3		2			3			2	2		2		2	3		1				2		2		NA	NA	NA
Polygonia c-album	O		2		2	1	1	3		1		2	1	1				2	1	1	2	1		2		2	2	2	2		2	2	1	NA	NA	NA
Polyommatus bellargus	O	1	3			2			3								2					2	2						3				NA	NA	NA
Polyommatus daphnis	O	1															1						3				2						NA	NA	NA
Polyommatus dorylas	O	1	1														2	1					1										NA	NA	NA
Polyommatus icarus	O		3	2	2	2	2	3	3	2	3	1	1	3	3		3	3	2	2	4	3	3	2	1	4	4	3	3	3	1	2	2	NA	NA	NA
Polyommatus thersites	O	1															2						1		1								NA	NA	NA
Pyrgus alveus	O	1														1															1		NA	NA	NA
Pyrgus malvae	O		2	1		2	2	1	2	2		2				3			2		1	2	2		1	2	2	2	2	1	2	2		NA	NA	NA
Pyrgus serratulae	O	1																			1												NA	NA	NA
Satyrium pruni	W		1								1	1																		2		1		NA	NA	NA
Satyrium spini	W	1																				1	1											NA	NA	NA
Thecla betulae	W			1			2										2											1			2		NA	NA	NA
Thymelicus lineola	O		4		2	2	2		2	2	4	2		2		3	2	2				3	3	2	1	2	2	1	2	2	3	2	1	NA	NA	NA
Thymelicus sylvestris	O		2		3	2	2	1	3		2	5		2	2		2	3		2	1				1				3	3	2	2	2	NA	NA	NA
Thyris fenestrella	W																								1									NA	NA	NA
Vanessa atalanta	O		1			1	2	2	1	1	2	2	1	1		1	1	2	2	2	1		1	1	1	2	2	2	1		2	1		NA	NA	NA
Vanessa cardui	O		4	2			2	2	3	1	2	3	1	2	1	1	1	2	3	2	1	4	4		1	4	4	2	4			2	2	NA	NA	NA
Zygaena angelicae	O					2						2								2										2				NA	NA	NA
Zygaena brizae	O	1	2																															NA	NA	NA
Zygaena carniolica	O								2		2	1																						NA	NA	NA
Zygaena ephialtes	O					1											2					3	3											NA	NA	NA
Zygaena filipendulae	O		2		1	2		5	3	2	3	2		5	2					5				2		2	2	2		3			2	NA	NA	NA
Zygaena lonicerae	O	1	2						1		2	3			1		3																	NA	NA	NA
Zygaena loti	O				2	3			3		2	2					3					2	3											NA	NA	NA
Zygaena purpuralis	O		2						1			2										1								2				NA	NA	NA
Zygaena viciae	O				3	3					3	3	2	4			3	2						3		5		3		2				NA	NA	NA

Table S8 Moth dataset. Species abundances were expressed on an ordinal scale as follow: 1 – 1 specimen; 2 – 2–10 specimens; 3 – 11–50 specimens; 4 – 51–100 specimens; 5 – >100 specimens.

ID site			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Species	**Open-country (O) /Woodland (W)**	**Regionally Important Species**	Starohrozenkovský lom	Kladná	U Petrůvky	Štítná – stráň nad dráhou	Ploščiny	Záhumenice	Bylnice – Na stráži	Suchov – nad Ostrožankou	Nová hora	Bílé potoky	Podhradské louky	Mechnáčky	Cestiska	Kaňoury	Javorník – pod Hradiskem	Žerotín	Hutě	V Krátkých	Kútky	U Megovky	Podlučí	Končiny	Drahy	Machová	Rybnické údolí pod Machovou	Přední louky	Dolnoněmčanské louky	Paseky u Nedašovy Lhoty	Sidonie – pastvina na hranici	Javorina	Jamy u Březové	Lopenické sedlo	Skleněný vrch	Hrnčárky
Abraxas sylvata	W				1			2		2			2	2				2				2			2		1				NA	NA	NA		
Abrostola asclepiadis	O	1			2													2									2				NA	NA	NA	1	
Abrostola tripartita	O		2		1	1	1	2		2	3	1	2		2		2				1			2	1		2	1	1	2		NA	NA	NA	2	
Abrostola triplasia	O		1				2	1		2		1	2	2		1		1		2	2			2		1		2	2			NA	NA	NA	2	1
Acasis viretata	W	1					1						1						1								1		1			NA	NA	NA		
Achlya flavicornis	W		1																										3		2	NA	NA	NA	1	
Acosmetia caliginosa	O	1							1																	1	1					NA	NA	NA	2	
Acronicta aceris	W		1					2	1						2		1	2					1	2				2				NA	NA	NA	2	
Acronicta alni	W		1		1		2	1			1	1	2		1					2	1					1	1		1	1	2	NA	NA	NA		
Acronicta auricoma	O			1	1	2	2		2	2	2	1	2	2		2	1	3		1	2	1	1	3	2	2	1	2	2	1	2	NA	NA	NA	2	1
Acronicta leporina	W		2	2	2		2	1	1	2	2	2	1		1				1	2		1		2	1	2			1	1	2	NA	NA	NA		1
Acronicta megacephala	W				1	1			1	2	2			2								1	1	2	2	2	2	1	2	1	2	NA	NA	NA	2	1
Acronicta psi	W		2		1	1		1					2	2	1	2		2	1		2			2		2					2	NA	NA	NA		1
Acronicta rumicis	O		2		1	1	2	2	2	2	2	1		2		2	1	2	1	2	2		2	2	2	1	1	2	2	1	2	NA	NA	NA	2	2
Acronicta tridens	W		2		1			1					2		2				1				1	3		2	1					NA	NA	NA		
Actinotia polyodon	O		2		2	1	1	2	1	2	1	1	2		2	2		2	2	2		2	1	3	2		1	3	1	2	2	NA	NA	NA	2	2
Aedia funesta	O		2								2							1			1		1		1			2				NA	NA	NA		
Aethalura punctulata	W				1	2	1					1				1	2		1					1						2	NA	NA	NA		
Aglia tau	W			2		1	1		2			1		2		1	1		1	1		1					2		1		1	NA	NA	NA		
Agriopis aurantaria	W																							1								NA	NA	NA		
Agrius convolvuli	O		1				1	1			1		1	2			1	2		1	2	1	1		2		1		1			NA	NA	NA	1	
Agrochola circellaris	O		2		1		2	2	2			2	1	2	1						2	2	2	3	2	2	1	1	2			NA	NA	NA		2
Agrochola helvola	O		2	2			2	1		2	3	2	2	2	2		2	2		2	2			3	2				3	2		NA	NA	NA		
Agrochola humilis	O		2					2					1	2	2			2	1	1	2		1	1	1		2					NA	NA	NA	2	
Agrochola laevis	O					1			2					2							3	2										NA	NA	NA	2	
Agrochola litura	O		2	2	2	2	2	2	2		1	2	2	2	2	1	1			2	2	1	1		2	2	2	2		2	2	NA	NA	NA	2	
Agrochola lota	W	1								1												1		1	1							NA	NA	NA		

Agrochola lychnidis	O		2					1	1	1				2	1						2		2		1	2				2		NA	NA	NA		
Agrochola macilenta	O		2	2	1		1	1				2	1				1	2		2		1	2	3	2	2			2	2	2	NA	NA	NA		
Agrochola nitida	O						2					2																				NA	NA	NA		
Agrotis exclamationis	O		2	3	2	3	2	3	4	3	3	2	3	2	3	2	2	2	2	2	2	2	2	3	3	2	2	3	2		2	NA	NA	NA	2	2
Agrotis ipsilon	O				1	2	2		2	1	2	2		2				2	2		2	2	2	2	1			2	1	1		NA	NA	NA	2	1
Agrotis segetum	O		2				2	2		2	3	2	1	2	2		2	2			2			2	3		2	3	2	1	1	NA	NA	NA	2	
Alcis bastelbergeri	W	1			2		2									3			1	1		1		3	1		2	2	2	1	2	NA	NA	NA	2	3
Alcis repandata	W		2	2	2		2	2		2	2	2	3	2	2	3	2	2	2	2	2	2	1	2	2		2		2		2	NA	NA	NA	2	1
Allophyes oxyacanthae	W		1		1		2			2	2			2				1			2		3	2	3				2			NA	NA	NA		
Alsophila aescularia	W		1										1		1								1	1					2	1		NA	NA	NA		1
Amata phegea	O						2										2															NA	NA	NA		
Ammoconia caecimacula	O		1	2	2			2	2	2	2		1	2	2	2	1	2		1	2	2	2	3	3	3	3	2		2		NA	NA	NA	2	
Amphipoea fucosa	O				2			1		3	3		2	2		3	1	2		1	2			2	3		2		2		2	NA	NA	NA	2	2
Amphipoea oculea	O		2	1	2	1	2	2			2	2	1		1	3		2	1	2	2			2	2				2	1	3	NA	NA	NA	2	
Amphipyra berbera	W												1		1					1		1			2	2		2	1		1	NA	NA	NA		
Amphipyra livida	O	1																								3						NA	NA	NA	1	
Amphipyra perflua	W	1			1		2							1						1												NA	NA	NA		
Amphipyra pyramidea	W				2	1	2	1	1	1		2		2		1	1	2	2	2	2	1	2	2	2	2	2	2	1		2	NA	NA	NA	2	2
Amphipyra tragopoginis	O						2	1	1		1	2	1			3				1		1	1	1	1	2	1	1	1		3	NA	NA	NA		
Anaplectoides prasinus	W		2		1		1	2	2	1		1	2	1	1						1	2		2			2		1			NA	NA	NA		2
Angerona prunaria	W		2	1	2	2	3	2	1	2	2	2	2	2	2		2	2		2	2	2	2	2	3	2	2		2	2	2	NA	NA	NA	2	2
Anorthoa munda	W		2	2		1								1		2			1	1	2		2	2	2	2		2	1	1	1	NA	NA	NA	2	1
Anticlea derivata	W				2	1							1																			NA	NA	NA		
Antitype chi	O						1					1							1						1				1			NA	NA	NA		
Apamea anceps	O		2				1						1		2									1	3	1						NA	NA	NA	1	
Apamea crenata	O		2		2		2	1	2	1	2		2		1			1	2	2		1		2			2				2	NA	NA	NA		
Apamea epomidion	O	1	2						1													1										NA	NA	NA		
Apamea furva	O	1									1																					NA	NA	NA		
Apamea lateritia	O						2				1																					NA	NA	NA		
Apamea lithoxylaea	O			2	1	2			2		2		2			1							1					1			1	NA	NA	NA		
Apamea monoglypha	O		2	2	2	1	2	2	3	2	2	2		2	2	2		2	2	2	2	2	2	3	2	1	1	3	2		2	NA	NA	NA	2	2
Apamea ophiogramma	O					1		1	1									1						1		1						NA	NA	NA		
Apamea remissa	O	1	1					2																								NA	NA	NA		
Apamea scolopacina	O								1						2							1					1		1			NA	NA	NA		
Apamea sordens	O		1		2						1								1		1			2				3				NA	NA	NA	2	
Apamea sublustris	O				2				2	2			2			2				1	2		1	2	2		1	2	1		1	NA	NA	NA		
Apamea unanimis	O	1	1																													NA	NA	NA		
Apeira syringaria	W	1								1			1						2						1	1		1				NA	NA	NA		
Aplocera plagiata	O			2						2	2			2		1	2	2		1	2				2	1	2		2	1	2	NA	NA	NA	2	
Aplocera praeformata	O		2				1	2			3	1	2		2	2				2				3			1		2	1		NA	NA	NA		
Apocheima hispidaria	W				2																											NA	NA	NA		
Apoda limacodes	W		2	2	2	1	2	2	2	3	3	1	3	3	2	1	2	2	3	3	2	2	2	2	3	2	3	2	2		1	NA	NA	NA		2

Aporophyla lutulenta	O	1						1	2		2			2		2		1	1	1	2						1					NA	NA	NA	1	
Arctia caja	O		2				1		1		2	2	2	1		2	1	2	2			1	1	2	1	2	2		2		2	NA	NA	NA		2
Arctia villica	O																2															NA	NA	NA		
Arctornis l-nigrum	W		1	1	2	1	1	2	1	1	1		2	2	2			2	1	2		3		2		2	2	2	2			NA	NA	NA	2	2
Artiora evonymaria	W												1				1								1		2		2			NA	NA	NA		
Ascotis selenaria	O		2		2	2		2	2	2	3		2	2	2	1	2	2		2	2	2	2	2	3	1	2	1	2	1	1	NA	NA	NA	2	2
Asteroscopus sphinx	W																													2		NA	NA	NA		
Asthena albulata	W					1				1						1			1					2	1			1	1		3	NA	NA	NA		
Asthena anseraria	W	1																						1								NA	NA	NA		
Atethmia ambusta	W	1																							1							NA	NA	NA		
Atethmia centrago	W			1	1					2			2	2			2	2		1	2		2		2	2	1	1	1			NA	NA	NA	2	
Athetis pallustris	O															2			1												1	NA	NA	NA		
Atolmis rubricollis	W		1	2	2		2			2		1	2							2		1	2					1	1			NA	NA	NA		
Atypha pulmonaris	O		2		2		1	2			3		2	2	2	1	1	2	1			1	1	2				2	3			NA	NA	NA	2	2
Autographa bractea	O		1				1								1	1						1		1					1			NA	NA	NA	1	
Autographa gamma	O		1	2	2	2	2	1	2	2	3	2	2	2	2	2	2	2	2	2	1	2	2	3	2	2	2	3	3	2	3	NA	NA	NA	3	2
Autographa jota	O		2			1	1						1	1		1		2	1	2					1		2		1			NA	NA	NA		
Autographa pulchrina	O		2		1	1			1			1	1			1			2	2	1	2		2		2	1	1	1		1	NA	NA	NA		2
Axylia putris	O		2	2	2	2	2	2	2	2	4	2	2	2	2		2	3	2	1	2	2	2	4	3	2	3	3	3	2	1	NA	NA	NA	2	2
Bena bicolorana	W		1				1	1					2				1		1	1	2		1	1			2	1	2	2		NA	NA	NA		1
Biston betularia	W		2	1	2	2	2	2	1	2	2	2	2	2	2	2		2	2	1	2	2	2	2	2	1	2	2	1	2	2	NA	NA	NA	2	2
Biston strataria	W		1	1							1					2				1		1	1		2				1	2		NA	NA	NA	1	2
Brachionycha nubeculosa	W		1	1											1	1														1		NA	NA	NA		
Brachylomia viminalis	W		1				2	3			3	2	2	2	1	2		2	2	2	2	2		2	1		3	1	2		1	NA	NA	NA	2	1
Bupalus piniaria	W										1																				2	NA	NA	NA		
Cabera exanthemata	W		2		1					2	2				1	2	1			2				3	3	2	1				2	NA	NA	NA		2
Cabera pusaria	W		2				2	2	1	3	1	1	2	2	2	1	2	2	2	2	2	2	1	2	3		2	2	2		2	NA	NA	NA	1	2
Callimorpha dominula	O		1	2	2		1	2			1	1							1			2					1		1	2		NA	NA	NA		
Calliteara pudibunda	W		2	1	2	2	2	1	2	2	2	2	2	2	1	2			2	3	2	2	2	3	1	2	1	2	3	2	2	NA	NA	NA	3	2
Calocestra trifolii	O		2				2	1	1	1	3	2	1	2		1	1	2			2			2	2				2			NA	NA	NA	2	
Calophasia lunula	O								1				1	1	1																	NA	NA	NA	1	
Calymma communimacula	W	1																1														NA	NA	NA	1	
Campaea margaritata	W		2	2	2	2	2	3	3	2	3	2	3	2	3	2	2	2	3	2	2	2	2	3	3	3	2	3	3	2	2	NA	NA	NA	2	3
Camptogramma bilineatum	O		3	2	2	2	2	2	2	3	3	2	3	2	2	4	2	2	1	3	2	2	2	3	3	2	2	3	3	2	2	NA	NA	NA	2	2
Caradrina morpheus	O						1			1	2													2	2				2			NA	NA	NA		
Cataclysme riguata	O	1								1															1							NA	NA	NA		
Catarhoe cuculata	O		2		1			2	2	2	1		2	2	2	1		2	2	2	2	2	2	3	1	2	2	2	1			NA	NA	NA	2	2
Catarhoe rubidata	O		2																	1					1							NA	NA	NA		
Catephia alchymista	W	1		1																												NA	NA	NA		
Catocala electa	W	1																				1										NA	NA	NA		
Catocala fraxini	W		2		1	1	2	1				1			1		1		1		1	1	1	1	2	2	1	2	2	2		NA	NA	NA	1	1
Catocala fulminea	W		2	2	2	1	2	2	2	3	2	1	2	2	2	2	1	2	1	1	2	2	2	2	3	1	2	2	1	2		NA	NA	NA	2	2

Catocala nupta	W		1	1	1		1		1		2	1	1	2	1	1	1	1			2	1	1	2	2		1	2	2		1	NA	NA	NA	1	1
Catocala promissa	W												1								1					1						NA	NA	NA		
Catocala sponsa	W											1				1						1		1				1	1			NA	NA	NA	1	
Celaena leucostigma	O								1																							NA	NA	NA		
Cepphis advenaria	O	1																									1					NA	NA	NA		
Ceramica pisi	O		2	2	1	2		2	2	2	3		2	2	2	2	1	2		3	2	2	2	3	2	2	1	2	2	2	2	NA	NA	NA		2
Cerapteryx graminis	O			1	2		2	2	2		1	2				2			2				1				2	1	1	2	NA	NA	NA	1	
Cerastis leucographa	O		1				1			1		2			1		1			1		1	1		1	1	2	1	1			NA	NA	NA		
Cerastis rubricosa	O		1		2	3	2	2	2	2	1	2		2		2	2	2	2	2		2	3	2	2	2	2	2	2	2	3	NA	NA	NA	3	1
Cerura erminea	W		2		1	1		1			1		1	1	1			1	1	1	1							1				NA	NA	NA		
Cerura vinula	W								1													2										NA	NA	NA		
Charanyca trigrammica	O		2		2	2	2		2	2	3	2	3		2	2	1	2	2	3	1	1	1	3	2	3	2	3	2	2	1	NA	NA	NA	1	2
Charissa obscurata	O		3				1					2			2													1				NA	NA	NA		
Chersotis cuprea	O															1																NA	NA	NA		
Chiasmia clathrata	O		2		2	2	2	3	2	3	4	2	2	3	2	3	2	3	2	3	3	3	3	3	3	2	2	3	3	2	2	NA	NA	NA	3	2
Chloantha hyperici	O		1																													NA	NA	NA		
Chlorissa cloraria	W		3	1	2			2		1	1	1	2	2	1	1	1	2	1	2	2			3	2	3	1	2	1	1	2	NA	NA	NA	2	2
Chlorissa viridata	W		2	1	2	2	2	2	3	2	1	1	2		2	2	2	1	1	1	1	2	2	2	2		1	2	1	2	2	NA	NA	NA	2	
Chloroclysta miata	W	1						1					1																			NA	NA	NA		
Chloroclysta siterata	W			1			1	1			2			2						2	2	2		3		2			1		2	NA	NA	NA	1	1
Chloroclystis v-ata	O		2	1			2	2			2		2	2	2	1	1	2	2	1	2	2	1	3	2	2	2	2	2			NA	NA	NA	2	1
Cidaria fulvata	W		2	2	2		2	2	1	3	3	1	2	1	2	2	2		1	1	2	2	2	2	3	2		2	2	2	2	NA	NA	NA	2	1
Cilix glaucata	W		1			2	2		2	3	2	2	1	2			1	2		2	2	1	2	2	2	2	1	2	2			NA	NA	NA	2	2
Cleoceris scoriacea	O	1	1		2	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2		2		2	3	2	2	2	2		NA	NA	NA	2	2
Cleora cinctaria	O					1	1		1	1		1			2	2	2		2	2		2	2	1		2	2	2	1		2	NA	NA	NA	2	
Clostera anachoreta	W	1				2					1								1					1								NA	NA	NA		
Clostera anastomosis	W																									1		1	1			NA	NA	NA		
Clostera curtula	W				1		1	1			1		1		1							1				1	2			1	1	NA	NA	NA		1
Clostera pigra	W		1								1		2	1		2		1		1		1		2		1	1			1	NA	NA	NA		
Colobochyla salicalis	W										1			1		1					1	1		1							NA	NA	NA		
Colocasia coryli	W		4	1	3	2	2	2	2	2	3	2	3	3	2	2	3	2	2	3	3	3	3	3	2	3	3	3	3	2	2	NA	NA	NA	2	2
Colostygia olivata	O		1		1								2		1	2						1		2	2	1	2	2	2		1	NA	NA	NA		
Colostygia pectinataria	O		3	2	2	2	2	2	2	2	3	2	3	2	3	2	3	2	2	1	2	2	3	3	2	2	2	3	3	2	2	NA	NA	NA	2	2
Colotois pennaria	W			1				1																					2			NA	NA	NA		
Comibaena bajularia	W	1	1							1			2							2				2		1	2		1			NA	NA	NA		2
Conisania luteago	O		3										2																			NA	NA	NA		
Conistra erythrocephala	O		2	1			2					2	1			1	1	2	2			2	2		2	2	1			2	1	NA	NA	NA	1	2
Conistra rubiginea	O		2		2	2	1	2	1	2			2	2	2	2	1			2	1		2			3		2	1	2	2	NA	NA	NA	2	
Conistra vaccinii	O		1		2	3	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2		2	3	2	2	2	2	1	2	NA	NA	NA	2	2
Coscinia cribraria	O					1																										NA	NA	NA		
Cosmia affinis	W	1					1		1					1				1			1	1	2		2								NA	NA	NA	1	
Cosmia diffinis	W	1											2																			NA	NA	NA		

Cosmia pyralina	W		1				2	2	2	2	3	1	2	2	2	2	1		2	1	2	2	1	2	2	2		2				NA	NA	NA	2	2
Cosmia trapezina	W		2	1	2	1	2	2	2		3	2	2	2	2	2		2	2	2	2	3	2	3	2	1	2	3	2		2	NA	NA	NA	3	2
Cosmorhoe ocellata	O		2	2	2	2	2	2	1	2	2	1	2	1	2	2	1	2	2	2	2	2	2	4	3	2	2	2	2	2	1	NA	NA	NA	2	2
Cosmotriche lobulina	W							2	1						1					1						1						NA	NA	NA		
Cossus cossus	W		1			2	1		1		1		2		1								1	1	1	1		1				NA	NA	NA		
Costaconvexa polygrammata	O	1																							1							NA	NA	NA		
Craniophora ligustri	W		3	1	2	2	2	2	2	2	3	2	3	2	2	2	2	2	2	2	2	2	2	3	3	2	3	3	2		2	NA	NA	NA	2	2
Crocallis elinguaria	W		1				1			1	2		1			2							1		2	2	2			2	1	1	NA	NA	NA		
Cryphia algae	W		2				1	2	2	1	2		2	2	2	1	1	2	1		2	2		2	2	3		3	2			NA	NA	NA	2	2
Cryphia domestica	O		2																													NA	NA	NA		
Cryphia ereptricula	O																															NA	NA	NA	2	
Cryphia fraudatricula	W																2															NA	NA	NA	1	
Cucullia lactucae	O					1			1																							NA	NA	NA		
Cucullia lucifuga	O							1									1						1								1	NA	NA	NA		
Cucullia prenanthis	W	1								1					1																	NA	NA	NA		
Cucullia umbratica	O		1			1			1		1											1		2			1	1	1		NA	NA	NA	1	
Cucullia verbasci	O		1																													NA	NA	NA		
Cybosia mesomella	O		1				2	1			1	2	2				1		2	1			1	3	2		2	2			2	NA	NA	NA		2
Cyclophora albipunctata	W		2											1						1				2			1				1	NA	NA	NA		
Cyclophora annularia	W		2		1	1	1	2		2	2		2	2	2			1			1	2	1		2	2		2	1	1	2	2	NA	NA	NA		
Cyclophora linearia	W								1		3		2			1				2	1			3	3	2	2	2	2	2	1	NA	NA	NA		1
Cyclophora porata	W												2							1				1								NA	NA	NA		
Cyclophora punctaria	W		2		1	2			1	1			2		2	1	1		2	2		1		2	2	2	2	1	2		2	NA	NA	NA	2	
Cyclophora quercimontaria	W	1	2																					1								NA	NA	NA		
Cyclophora ruficiliaria	W		2							1			1									1		1	1							NA	NA	NA		
Cymatophorina diluta	W		2				2	2	1	2	2	2	2	2	2	2		2	3	3	2	1	1		1	2	3	2	4		2	NA	NA	NA	2	2
Deilephila elpenor	O		2	2	2	1	2	1	1	3	2	1	2	2	2	1		2	2	2	2	1	2	3	2	2	2	2	2	1	1	NA	NA	NA	2	2
Deilephila porcellus	O		3	2	2	2	2	3	2	3	3	2	3	3	2	3	2	2	1	2	2	2	3	3	4	2	3	2	2	2	1	NA	NA	NA	3	2
Deileptenia ribeata	W		2		2	1	1	2				2	2	1	2			2			1											NA	NA	NA		
Deltote bankiana	O		1			1		1	2		2										2			3			2				3	NA	NA	NA		
Deltote deceptoria	O		2		2	2	2	2	2	3	3	2	2	2	2	2	2	3	3	2	2	3	2	3	2	2	2	3	2		3	NA	NA	NA	2	3
Dendrolimus pini	W		2	1	2	1	2		1	2	2	2	1	2	2	1	1		2	1	2	2	2	2	2	1	2		2			NA	NA	NA	1	1
Diachrysia chrysitis	O		2	2	2	2	2	2	2	1	3	1	2	2	2	2	1	2	2	2	2	2	2	3	2	2	2	3	3	2	1	NA	NA	NA	2	2
Diachrysia chryson	O	1	1		1		1				1													2			1	1	2	1		NA	NA	NA		2
Diacrisia sannio	O		2		2	2	2		3	2	3	2	1			3	2	1	2	3	2	2	2	3		2	1	2	2	1	3	NA	NA	NA	3	2
Diaphora mendica	O		1				1	2			2	1	2		2	2					1		2		2		1	2		1		1	NA	NA	NA		1
Diarsia brunnea	O		2		1		1	2		1	3	1		1	1	2							2		3	2	1	2	1	3		1	NA	NA	NA		
Diarsia rubi	O															1													1			NA	NA	NA	2	
Dicallomera fascelina	O																						2									NA	NA	NA		
Dichonia convergens	W				1								1					2														NA	NA	NA		
Dicycla oo	W	1	2					2					2								2			1		2	2	2	1			NA	NA	NA	2	
Diloba caeruleocephala	W		1	1	1		1	2		2	3	2		2	2		1	2	2	2	3	1	2	3	3	2	2	2	1			NA	NA	NA	2	

Drepana curvatula	W	1								1	1											2		2	1	1	1	1				NA	NA	NA		2
Drepana falcataria	W			2	2	1	2	2	2		2	1	2	2	2	2	1	2	2	2		2	2	2	2	2	1	1	2	2	2	NA	NA	NA	2	2
Drymonia dodonaea	W		2		2	2	2	2	1	3	3	2	2	2	1	3		2	2	2		1	2	2		2	2	3	1	2	3	NA	NA	NA	3	2
Drymonia obliterata	W	1	1		2			2			2		2	2	1		1		1	2		2		1		2	2			1	1	NA	NA	NA		2
Drymonia querna	W				1			2	2		1		1	2	1	2		1		2	2	2	2	2	1	3	2	2	1			NA	NA	NA	2	
Drymonia ruficornis	W			1		1	2	2	2	1	1	2	2	2	2		2	2	2	2	2	2	4	2		3	2	2	1			NA	NA	NA	3	
Drymonia velitaris	W	1																											1			NA	NA	NA		
Dryobotodes eremita	W							1													2		1			2	1					NA	NA	NA	2	
Dypterygia scabriuscula	O		1										2																	1		NA	NA	NA		
Dysstroma citrata	O						2			2		2			1					2		1		3				2			2	NA	NA	NA		2
Dysstroma truncata	W		3	2	2	1	2	3		2	3	2	3	2	3			2	2	1		2		3	1	3		3	2	2	1	NA	NA	NA		2
Earias clorana	W			2					1		2													2	1					2		NA	NA	NA		1
Earias vernana	W																						1									NA	NA	NA		
Earophila badiata	W				1	2			2		1			1		2	1			2		2	2	1	2	2		2	2	1	1	NA	NA	NA	2	
Ecliptopera capitata	W			1	1			2		1			1	2	2			2	1	2	2	2		2			1		1			NA	NA	NA		
Ecliptopera silaceata	W		2	1	2		2	2	2	2	2	1	2	2	2			2	1	2	2	2	1	4	2	1	2	2	3		2	NA	NA	NA	2	2
Ectropis crepuscularia	W		1		2	1	2	1	1	1	2	1	2	1	1	2			2	2		1	1		2	2	2		2		2	NA	NA	NA	2	2
Egira conspicillaris	O			1	2	2			2	2			2	2			2	2	2	2			3	2	1	3	2	2	2	2	1	NA	NA	NA	3	2
Eilema complana	O		2	1		2	2	2	2	3	3	2	2	2	2	3	3	3	2		2	2	3	3	3	3	3	2	2	2	5	NA	NA	NA	2	2
Eilema depressum	W		2	1			2	1	1	2	2	2	2		1	2	2	2	2	2	2	3	2	2	2	2	3	1	2		3	NA	NA	NA		2
Eilema griseola	W							2		2	2											2		3	1			2	2	2		NA	NA	NA	1	
Eilema lurideola	W			1	2	2	2		2			2		2		2		2	2	2	1	2	2	2		2	3		2		3	NA	NA	NA		1
Eilema lutarella	O								2	1			1								2		2	3				2		2	3	NA	NA	NA	3	
Eilema pygmaeola	O								2														2					2				NA	NA	NA		
Eilema sororcula	W		2	2	2	2	2	2	1	2	3	1	2	2		2	1	2	2	3	2	4	3	2	2	3	2	2	2	2	2	NA	NA	NA	1	2
Elaphria venustula	O		1							2					1		1		2					2		2	1				1	NA	NA	NA	2	
Electrophaes corylata	W		3					2		1	2		3	2	2			2			2	1				1	2	2	1			NA	NA	NA	2	
Ematurga atomaria	O		2	1	2	2	1	2	3	3	2	1	2	3	3	2	4	3	1	2	3	3	2	3	3		1	3	3		2	NA	NA	NA	2	2
Emmelia trabealis	O		2	1		2	2	2	2	2	4	2	2	3	2			3			3	1		3	2	2		2	2	1		NA	NA	NA	2	
Enargia paleacea	W		2		1		2	1				2			1				1											2	2	NA	NA	NA	1	1
Endromis versicolora	W		1				1					2				2									1		1			2		NA	NA	NA	1	
Ennomos autumnaria	W						1	1		1		1			1			2						1	2	1		2	1			NA	NA	NA	2	
Ennomos fuscantaria	W				1				1	1			1					2	2	2	1		1	2		2	2		1			NA	NA	NA	1	
Ennomos quercinaria	W							1					1		1	1						1			1		1					NA	NA	NA		
Epichnopteryx plumella	O																												1			NA	NA	NA		
Epione repandaria	W					1				1	2					1									1				2			NA	NA	NA		
Epirrhoe alternata	O		2				2	2	2	2	3	2	2	2	2	3		2	1	2	2	2	2	4	3	2	2	2	3	2	2	NA	NA	NA	2	2
Epirrhoe galiata	O	1		1																				1	1					1		NA	NA	NA		
Epirrhoe molluginata	O										2													3								NA	NA	NA		
Epirrhoe pupillata	O	1	1					2					2	2	2			2			2		1			1	2					NA	NA	NA	2	
Epirrhoe rivata	O	1						1								1		2		2						2	2				1	NA	NA	NA		
Epirrhoe tristata	O		2		2	2		2	1		2		2	2	1	2	1	2		2	2	2	2	3	3	3	3	2	2	2	2	NA	NA	NA	2	

Epirrita autumnata	W							1			2				1							2					2					NA	NA	NA		
Epirrita chrystii	W													2							2											NA	NA	NA		
Epirrita dilutata	W							2					2		2										2							NA	NA	NA		
Erannis defoliaria	W														1								1									NA	NA	NA		
Eublemma purpurinum	O			1		2			2									2							1		2		1			NA	NA	NA		
Eucarta virgo	O		1			2			1		2			2				2			2	1			1			2				NA	NA	NA	1	
Euchalcia modestoides	O	1	1		2	2			2			1	2			2	1		2	1	2	1	1			2		3	2			NA	NA	NA	1	2
Euchoeca nebulata	W		1					1																1					2	2		NA	NA	NA		2
Euclidia glyphica	O				1		2	2	1	2	3	2	2	3		2	2					2	4	2	2	1	2		3			NA	NA	NA	2	
Euclidia mi	O										2					2	2													1	2	NA	NA	NA		
Eugnorisma depuncta	O															1																NA	NA	NA		
Eulithis mellinata	W		2																										1			NA	NA	NA		
Eulithis populata	W						2					1																				NA	NA	NA		
Eulithis prunata	W														1													2		1		NA	NA	NA		
Eulithis pyraliata	O		2	1	2	2		3	2	3	3		3		3	3	2		2	3	3	4	3	2	3	2	3	4	2		3	NA	NA	NA	3	2
Euphyia unangulata	O		2		1		2		1		1	1			2	2	1	2	1	2			1	2		1			1		2	NA	NA	NA	2	
Eupithecia abbreviata	W							2	2		1					1	2			2		2	3		1	3	2	2	2			NA	NA	NA	2	
Eupithecia abietaria	W						1			1	1			2		2	1			2	2						2		1			NA	NA	NA		
Eupithecia absinthiata	O																							2								NA	NA	NA		
Eupithecia actaeata	W	1												1							2											NA	NA	NA		
Eupithecia centaureata	O		2				2	2	2	1	1	1	2	2	2		1	2			2		1	2	2	1	2		2		1	NA	NA	NA	2	2
Eupithecia denotata	O								1											1		1										NA	NA	NA		
Eupithecia dodoneata	W						1																		1			2				NA	NA	NA		
Eupithecia ericeata	W	1																1							5							NA	NA	NA		
Eupithecia exiguata	W						1			2	1						2			2					1		1					NA	NA	NA		
Eupithecia haworthiata	W																														1	NA	NA	NA		
Eupithecia icterata	O		2	1			1	2	1		3	1	2		2	2	2	2	2	2		2	2	2	1	1		2	2		1	NA	NA	NA		
Eupithecia innotata	O																					1										NA	NA	NA		
Eupithecia insigniata	W	1	2						1		1			1			2		1									2	2			NA	NA	NA		
Eupithecia intricata	W	1																							1			1				NA	NA	NA		
Eupithecia inturbata	W	1																										2				NA	NA	NA		
Eupithecia lanceata	W		1				2					1								1							2		2		1	NA	NA	NA		
Eupithecia lariciata	W									1						2				2				2	1		2					NA	NA	NA		
Eupithecia linariata	O																1									1						NA	NA	NA		
Eupithecia millefoliata	O								1		1																					NA	NA	NA		
Eupithecia plumbeolata	O						1													2									1			NA	NA	NA		
Eupithecia pusillata	W						2					1													1				1		1	NA	NA	NA		
Eupithecia satyrata	O				1	1										2				2												NA	NA	NA		
Eupithecia selinata	O									2														2				2				NA	NA	NA		
Eupithecia simpliciata	O	1	1																													NA	NA	NA		
Eupithecia subfuscata	O						2		1	2	1					2	2							2	1			2	1			NA	NA	NA		2
Eupithecia subumbrata	O															1								2								NA	NA	NA		

Eupithecia succenturiata	O		2				2			2	2	1	1			1								2					2			NA	NA	NA		
Eupithecia tantillaria	W				2	2	2		2	2	3	1				2				2		2		2	2				2			NA	NA	NA		
Eupithecia tenuiata	W																									1						NA	NA	NA		
Eupithecia tripunctaria	O						2			1						1				1								2	1			NA	NA	NA		
Eupithecia trisignaria	O	1					1																	1								NA	NA	NA		
Eupithecia venosata	O		1																													NA	NA	NA		
Eupithecia virgaureata	O					2																1			1				2			NA	NA	NA		
Eupithecia vulgata	W						1				2																					NA	NA	NA		
Euplagia quadripunctaria	O	1	3	2	1	2	2	1	2	1	1	2	2		1	2	2	2		1	2	2	2	3	1	3	2	2	2	2	2	NA	NA	NA	2	1
Euplexia lucipara	O		2	1	1		2	1	1	1	2	1	2	1	2			1	2	2	1	1		2		2	2	1	2			NA	NA	NA		2
Euproctis chrysorrhoea	W					1				1												1		1								NA	NA	NA		
Euproctis similis	W										3																					NA	NA	NA		
Eupsilia transversa	W		2		1	2	2	2	2	2	2	2	2	2	2	2	1	2		2	2	2	2	3	3	2	2	2	2		1	NA	NA	NA	2	3
Eustroma reticulatum	W						2	2		1		1			2				1			1		2			2		2			NA	NA	NA		2
Euthrix potatoria	O		2	1	2	2	1	2	1	2	1		2	2	1	2	1	2	1		2	2	1	3	2		2	1	2		2	NA	NA	NA	2	2
Euxoa aquilina	O									1								1							1							NA	NA	NA		
Euxoa nigricans	O						2																									NA	NA	NA		
Euxoa obelisca	O																1															NA	NA	NA		
Euxoa tritici	O													2				2			2											NA	NA	NA	2	
Falcaria lacertinaria	W		2				1				1	1	1		1				1		2										1	NA	NA	NA	1	
Furcula bicuspis	W		2		1		2	1				2	2	2	2			2		1		2						2				NA	NA	NA		2
Furcula bifida	W		2	2				1	1					1						1	2	2		2			1		2	1		NA	NA	NA		
Furcula furcula	W		1	2			2	1			2	2	1	1	1			2		1				2		1	2		1			NA	NA	NA		
Gastropacha quercifolia	W	1	1					1		2			1		1		1	2			2		2	2		2	1	1				NA	NA	NA		
Geometra papilionaria	W		1	1		1	1	1			2	1	1		1	1			1	1		1		3				2	2	2	2	NA	NA	NA		2
Gluphisia crenata	W		1		1			1					1		1		1		1	1	1	2		1		1	2					NA	NA	NA		
Gortyna flavago	O				1	2	1	1		2		1		2	1					1			2	2	2	1	2	1	1		2	NA	NA	NA		2
Griposia aprilina	W						1			2								1														NA	NA	NA		
Gymnoscelis rufifasciata	O								1									1					2	1				2	2			NA	NA	NA	2	
Habrosyne pyritoides	W		2	2	2	2	2	2	2	3	3	2	2	2	2	2	3	2	2	2	2	3	1	3	2	1	2	3	3	2	2	NA	NA	NA	2	2
Hada plebeja	O		2	2	2	1	2	2	2	2	3	1	2		2	1	1	2		2	1			2	2	2	2	2	2			NA	NA	NA	1	2
Hadena bicruris	O		1																													NA	NA	NA		
Hadena compta	O		2																													NA	NA	NA		
Hadena confusa	O																			2										2		NA	NA	NA		
Hadena perplexa	O													1				1			1											NA	NA	NA		
Harpyia milhauseri	W		1		1			1	1	1	1		1	2			2	1	1	1	2	1	2	1		1	2			2		NA	NA	NA		
Hecatera bicolorata	O	1												2			1	1										1				NA	NA	NA		
Hecatera dysodea	O		2																													NA	NA	NA		
Heliomata glarearia	O		2					2					2		3								1		2			2				NA	NA	NA		
Heliothis armigera	O		1		1	2	1	1	2	2	3		1	2			2	3			2		1	2	3	2			2			NA	NA	NA	2	
Heliothis maritima	O																							2								NA	NA	NA		
Heliothis viriplaca	O		1					2			2		2	1	2			2			1		1		1							NA	NA	NA		

Hemaris fuciformis	W	1					1					2					1	1	2												NA	NA	NA		
Hemistola chrysoprasaria	W		1				1		1	2	2	1	1	2		1	1	2							2	2			2			NA	NA	NA		2
Hemithea aestivaria	W				2			2	2	2	1		2		2					2	1		1	2	3	2	1	2	3			1	NA	NA	NA		1
Hepialus humuli	O										2							2			1				1					1			NA	NA	NA		
Herminia grisealis	W		2				2	2	2	2		2	2		2		2			2	1		2	2	3	1	2	2	2	2			NA	NA	NA	2	2
Herminia tarsicrinalis	W						1									1	1								2	2		1				2	NA	NA	NA	2	
Hoplodrina ambigua	O		2		1	2	2	2	2	2		2			2	2				2		2	2	3		2					NA	NA	NA	2	
Hoplodrina blanda	O		1		2		2	2	2	2	3	2	2	2	2	5	1	2			2	3	2	3	2	3		2	1		3	NA	NA	NA	2	2
Hoplodrina octogenaria	O		2		2	2	2	2	2	2	2	1			2	3	2		2	2		1	1	2	2	3	2	2	1		3	NA	NA	NA	2	2
Hoplodrina respersa	O	1														1															NA	NA	NA		
Hoplodrina superstes	O		1																												NA	NA	NA		
Horisme corticata	W																1	1			1			2		1					NA	NA	NA		
Horisme tersata	W		1		1			2			2		2		2			1			1		2		2	1		1	2		1	NA	NA	NA	2	1
Hydraecia micacea	O		2				1		2		2	1	1			2			1	1		1		2		2		2	1		1	NA	NA	NA	1	1
Hydraecia petasitis	O	1									1											1		2			1					NA	NA	NA		
Hydrelia flammeolaria	W		2	2	1			1					2		1				2	1		1				2		2	1		NA	NA	NA		1
Hydriomena furcata	W		2				1	2	1		1		2	2	2	3		2	2	2		2			1		2	4	2		2	NA	NA	NA		2
Hydriomena impluviata	W		2					2	1	1			2	2	2				1		2	3		2	1					2	NA	NA	NA		1
Hylaea fasciaria	W				2				1	1	2	1	1	2	1					1	2	1		2			2		2			NA	NA	NA		
Hyles euphorbiae	O	1													1											1						NA	NA	NA		
Hyles gallii	O							1		1			2		2						2			2	1			1		1		NA	NA	NA	2	
Hypena proboscidalis	O		2	2	3	2	2		2	2	3	2	2	2	2	2	2	1	2	2	2	3	2	3	3	2	2	3	3	2		NA	NA	NA	2	2
Hypena rostralis	O		1					2			2		2		2		1							4				2				NA	NA	NA		
Hypomecis punctinalis	W		1	1			2	2		2	3	2	2		2	1					1				1				1	2	2	NA	NA	NA	1	
Hypomecis roboraria	W		2	2	3	2	2	1			1	2	1	2	1	2		2	2	2	2		2	3	2	2	2	2	2	1	2	NA	NA	NA	2	2
Hyppa rectilinea	W								1																	1						NA	NA	NA		
Idaea aureolaria	O		1					1		3			1		1					2	2				3			2				NA	NA	NA	2	
Idaea aversata	O		2	2	2	1	1	2	2	2	3	1	2	2	2	3	2	3	2	3	2	2	1	3	2	2	2	2	2	2	2	NA	NA	NA	2	2
Idaea biselata	O		1	2	1		1	2		3	3		2		2		2	2		2	1	2	2	2	2	1	2			2	2	NA	NA	NA	2	2
Idaea degeneraria	O								1	2			1	2	1			2			2		1	1	1	1						NA	NA	NA	2	
Idaea deversaria	O									1														3	2	1			2			NA	NA	NA		
Idaea dilutaria	O																								3				2			NA	NA	NA		
Idaea dimidiata	O				1						2																		2			NA	NA	NA		
Idaea fuscovenosa	O										2																	2				NA	NA	NA		
Idaea humiliata	O		1	1	1			2		2	2		4		2		2	2	1	2	4	2	2	2	2		1	2	1			NA	NA	NA	2	
Idaea inquinata	O										2														1				1			NA	NA	NA		
Idaea muricata	O																1	2			2											NA	NA	NA	2	
Idaea ochrata	O			1						3	1				1						1				1		2	1				NA	NA	NA		
Idaea pallidata	O										2				1	1	1				1		1		2							NA	NA	NA		
Idaea rufaria	O																												2			NA	NA	NA		
Idaea rusticata	O																	2			2											NA	NA	NA	2	
Idaea serpentata	O		2	2				1	3	2			2	2	2	4		2		1	2		3	2		2						NA	NA	NA	3	

Idaea straminata	O								2	1													2		2							NA	NA	NA		
Idaea subsericeata	O	1																					1									NA	NA	NA		
Idaea sylvestraria	O	1																											2			NA	NA	NA		
Idia calvaria	W	1																					1									NA	NA	NA		
Ipimorpha retusa	W																1							1	1			2	1			NA	NA	NA	2	
Ipimorpha subtusa	W		3	1	2	2		2			2		2			1				2		2		1	2	2	2	1			2	NA	NA	NA	2	
Isturgia arenacearia	O		2					1		1	1		1	2	1		1						2	2	2		2					NA	NA	NA		
Isturgia roraria	O	1																						2								NA	NA	NA		
Jodis lactearia	W												1											2			2					NA	NA	NA		
Jodis putata	W																		1													NA	NA	NA		
Lacanobia aliena	O																															NA	NA	NA	1	
Lacanobia contigua	O		2		2	1	2	2	1	2	3	1	2	2	2		1	1		2		1	2	2	2	1	1	2	1	1	1	NA	NA	NA	2	2
Lacanobia oleracea	O		2		2	1	2	2	2	2	3	2	2		2		2	2		1		2	2	3	2	2	2	3	2			NA	NA	NA	2	2
Lacanobia suasa	O		2				2			2	2	2						1						3	2			3	1			NA	NA	NA	1	
Lacanobia thalassina	O				1	2			2	1	1			2				2			2			3	2			2				NA	NA	NA	2	
Lacanobia w-latinum	O								2	2	2					1							2	2	2			2				NA	NA	NA	1	
Lampropteryx suffumata	W		2	1	2		2	2		1		2		2	2					1		2	2	2		3	1		2	1		NA	NA	NA		1
Laothoe populi	W		2	1	1	2	1				2	1	1		1	2		2	2	1	2	2	1	2	2	2	2	1	1	2	2	NA	NA	NA	1	2
Lasiocampa trifolii	O									2	2		1	2				1		1	2	1	1	3		2			1	2	2	NA	NA	NA	2	
Lasionycta imbecilla	O		2	1	1	2	1	1	2				2			4			2	2				2		2	2	2	2		2	NA	NA	NA	1	
Laspeyria flexula	W		2	1	2	2	2		2	1	1	2	1	1	2	2	2	2	2	1	2	1	2	2	2	2	2	2	2		2	NA	NA	NA	2	2
Lemonia taraxaci	O	1			2		1		2				2			4			2		1		2		1	3	1	2	2		2	NA	NA	NA	2	
Leucania comma	O												1			2						1	2	2								NA	NA	NA		
Leucania obsoleta	O																										1					NA	NA	NA		
Leucodonta bicoloria	W	1			1								2							1	2	2							1			NA	NA	NA		
Leucoma salicis	W																											1				NA	NA	NA		
Ligdia adustata	W		2					1	2	2	2		2	3	1	1	2	2		1	3	1	2		2				2			NA	NA	NA	2	
Lithophane furcifera	W							1						2				1														NA	NA	NA	1	
Lithophane ornitopus	W		2	2	2	1	1	2	2	2		1	2	2	2	2	1	2	2		2	2	2	1	2	3	2	2	1	1	2	NA	NA	NA	2	2
Lithophane socia	W															2												1	1			NA	NA	NA		
Lithosia quadra	W		1		2		1		2	2	1	1			1	2	1	2	2			2	1	2		2		3	2		2	NA	NA	NA	2	1
Lobophora halterata	W		2														1		2							2	2				1	NA	NA	NA	2	
Lomaspilis marginata	W		2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	4	3	2	3	4	2	2	2	NA	NA	NA	2	2
Lomographa bimaculata	W		3		1	1	2	1		1	1	1	1	1	2	1			2		2	1		3	1	2	1				2	NA	NA	NA		2
Lomographa temerata	W		2	2	2		2	2	1	2	2	2	3	1	3	2	2		2	2		2	2	2	3	2	2	2	2	2	2	NA	NA	NA	2	2
Luperina testacea	O						1							1							1				1			2	1			NA	NA	NA		
Lycia hirtaria	W		2				1	2				1			2	2	1					2	2	3	3	2	1	2	2		2	NA	NA	NA	3	
Lygephila craccae	O		1	1																						2	1		1	2		NA	NA	NA		
Lygephila pastinum	O		2		2	3		1		2	3		1	1	1	1		1	2					1	2	2	2	2	2		2	NA	NA	NA	2	2
Lygephila viciae	O		2					2					1		2			2			2							3			1	NA	NA	NA		
Lymantria dispar	W										1						2	1	1	2	2	1	2	1	1	2	2	2	2			NA	NA	NA	1	2
Lymantria monacha	W		2	1	2	1	2	2		2		2	3	2	3	2	2	2	2	3	2	3	1	2	1	2	3	2	2	2	2	NA	NA	NA	2	3

Lythria cruentaria	O																	2						2								NA	NA	NA		
Lythria purpuraria	O												2														1					NA	NA	NA		
Macaria alternata	W		2			2	2	1	2	2	2	1		2	2	2	2	2		2	2	1	1	3	2		3	2	3	1		NA	NA	NA	2	2
Macaria brunneata	W																					2										NA	NA	NA		
Macaria liturata	W		2		2		2	2	2	2	3	1	2	2	2		1	1		1	2	2	1	4	2	1			2	1	2	NA	NA	NA	2	1
Macaria notata	W				2	2				2	3								1						2		2		2	1	2	NA	NA	NA	2	
Macaria signaria	W						2		1			2				1						2							1			NA	NA	NA		
Macdunnoughia confusa	O		2		1	2	1		1	1	3	1	1	2	2		1	2			2		2	3	1			2	3	2		NA	NA	NA	2	
Macroglossum stellatarum	O						1										1							1		1			1		1	NA	NA	NA		
Macrothylacia rubi	O		2	1	2	2	2	2	2	2	2	2	1	2	1		2	2	2	2	2	2	2	2	4	2	1		3	2	1	NA	NA	NA	3	2
Malacosoma castrense	O	1						1																								NA	NA	NA		
Malacosoma neustria	W		2	2	2	2	2		2	2		1			1				2		2	1	1						1			NA	NA	NA	2	
Mamestra brassicae	O		2				1	2	2	2	3	2	2	2		1	2	1		2	1	2		2	2		2	2	2	1	1	NA	NA	NA	2	1
Megalophanes viciella	O										2		2																			NA	NA	NA		
Meganephria bimaculosa	W	1																									1					NA	NA	NA		
Meganola albula	O						1		2	1	2		1	2			2		2	1	2	2	1	2	1				1			NA	NA	NA	2	1
Meganola strigula	W						1										1	2								1			2			NA	NA	NA		
Melanchra persicariae	O		2		2	2	2	1	2	1	3	1	2	2	2	2			1	1	2	1		3	1		2	2	2	2	1	NA	NA	NA	2	
Melanthia procellata	W		3	2	1	1		2			2		3		2		2	2			2	1	1	2	2					1		NA	NA	NA	3	2
Mesapamea secalella	O																	1			1			2							2	NA	NA	NA		
Mesapamea secalis	O		2		2	2	1	2	1	2	3		2	2		2		1		2	2	1	1	2	2	2		2	2		1	NA	NA	NA	2	2
Mesogona acetosellae	W	1		2																												NA	NA	NA		
Mesogona oxalina	W	1											1	2				2					2									NA	NA	NA		
Mesoleuca albicillata	W		2				1	2			2	1	2	2	2		1	2		2	2	2	1	3	1	1	2	2	1	2	1	NA	NA	NA	2	1
Mesoligia furuncula	O		1			2				2	4					1		2			2			2	2	2	2	2	2			NA	NA	NA	2	
Mesoligia literosa	O	1																2														NA	NA	NA		
Mesotype didymata	O						2					1																				NA	NA	NA		
Mesotype parallelolineata	O		1				2		2	2	2	1		3	2			2	2	2	2		2		2	1	1	2	2		1	NA	NA	NA		2
Miltochrista miniata	W		2	2	2	2		2	1	2	2		2	1	2	3	2	2	2	2	1	4		2	2		3	3			2	NA	NA	NA	2	2
Mimas tiliae	W		2	1	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	NA	NA	NA	2	2
Minoa murinata	O		1			1				2						1	2						1		2		1		2		1	NA	NA	NA		
Minucia lunaris	W							1										1					1									NA	NA	NA		
Mniotype satura	O		1		2		2			1	2	2	2				1		2			1		2	2	1		2	2		2	NA	NA	NA	2	1
Moma alpium	W		2	1	2		2	2				1	2	2	2	1	2			1	2	1	1	1	1	1	2	1		1	2	NA	NA	NA	1	
Mormo maura	O	1		1																												NA	NA	NA		
Mythimna albipuncta	O		3	1	2	2	2	2	3	3	5	2	3	2	3	3	2	2	3	2	2	2	2	3	3	3	2	3	3		2	NA	NA	NA	2	2
Mythimna conigera	O		2	1	2	2	1	2	3	2	4	1	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2	3	2		2	NA	NA	NA	2	1
Mythimna ferrago	O		1			1	1	2	2	2	2	1	2	2	2	3	2	2	2	2	2	2	2	3	2	2	3	3	2		3	NA	NA	NA	2	2
Mythimna impura	O		2	1		2	1	2	1	1	2		2	1	2	2			2	1		2	2	3	1			2	2		5	NA	NA	NA		
Mythimna l-album	O		1		1		1	1		2	2	1	2		1				1						2				3			NA	NA	NA		
Mythimna pallens	O		2		2	2	2	2	2	2	2	2	2	2	1	2	2	2		2	2	1	2	3	2	2	2	2	2	2	1	NA	NA	NA	2	2
Mythimna pudorina	O					2		2		2			2		2		1		2	1			1	3	1		2	2	1		3	NA	NA	NA		3

Mythimna straminea	O	1																								1						NA	NA	NA		
Mythimna turca	O		1										1										1	2								NA	NA	NA	1	
Mythimna vitellina	O									2			1	2	2		1	2		1	2		1	1	1	2	2		1			NA	NA	NA	2	
Noctua comes	O		1	1	1	2	2	1	2		2	2	2	2	1	2		1		1	1		2	1	3	2	2	3	2		1	NA	NA	NA		1
Noctua fimbriata	O		2	2	2	1	2	2	2	2	3	2	2	3	2	2		2	2	2	2	2	2	4	3	3	2	3	3	2	2	NA	NA	NA	2	3
Noctua interjecta	O	1																					1									NA	NA	NA		
Noctua interposita	O		2		2	1	2	2	3	1		1		2	2	2	2	2	3	2	2	1	3	3	2	2	3	2			2	NA	NA	NA	2	2
Noctua janthina	O		2	2	2	1	2	2	2	1	3	2	2	2	2	1	1	2	2	1	2	2	2	3	3	2	3	3	2	2	2	NA	NA	NA	2	2
Noctua orbona	O				2	1	1	1	1		1		2	2	1	1		2		1	2		1					2	1			NA	NA	NA	2	
Noctua pronuba	O		2	3	2	2	2	2	3	3	2	2	3	3	2	2	2	2	3	2	3	2	2	4	4	3	3	4	2	2	3	NA	NA	NA	2	3
Nola aerugula	O			1										1							1											NA	NA	NA		
Nola cicatricalis	W																											1				NA	NA	NA		
Nola confusalis	W													2				2		1	2			1	1							NA	NA	NA		
Nola cristatula	O																							1								NA	NA	NA		
Nola cucullatella	W									2										1	1	1	1	2	2	1	2		1			NA	NA	NA		
Nonargia typhae	O								1																							NA	NA	NA		
Nothocasis sertata	W		1					3			2		2	3	2			2		2	2	1	1		3	1						NA	NA	NA	2	
Notodonta dromedarius	W		2		2	2	2	2	1	2	3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	1	2	3	2	1	NA	NA	NA	2	2
Notodonta torva	W	1	1												1				1	2		1					1	1	1			NA	NA	NA		2
Notodonta tritophus	W		1		1		1		2		1			1	2			1	1		1		2	2	2		1		1	1		NA	NA	NA	2	1
Notodonta ziczac	W		1			2	1	1			3	1			1				2			2		3	2	2	2	2	2	1	1	NA	NA	NA		1
Nycteola asiatica	W										1						1								1			1	1			NA	NA	NA		
Nycteola revayana	W						1					1					1						1	2	1			1	1			NA	NA	NA		
Ochropacha duplaris	W						2	1			1								2			2		2					1			NA	NA	NA		1
Ochropleura plecta	O		2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	3	3	2	2	2	2	4	3	3	2	3	3	2	2	NA	NA	NA	2	3
Odezia atrata	O	1														5															2	NA	NA	NA		
Odonestis pruni	W		2	1				2		1	1		1	1	1			2	1		1	1		2	1		1	2	1			NA	NA	NA		1
Odontopera bidentata	W		1		2		1	1		1		1	2		1	2	1		2	2		2		3							2	NA	NA	NA		1
Odontosia carmelita	W	1		1	2		2					1							2	2										2	1	NA	NA	NA		
Oligia latruncula	O		2		1	2	2	2		2	3	2		2		1	2	2		2	2			2	2	2	2	2	1		1	NA	NA	NA	2	2
Oligia strigilis	O		2		2	2	2	2	2	2	3	1	3		3	2	3	2	3	3	2	2	1	3	2	2	2	3	2	1	1	NA	NA	NA	2	2
Oligia versicolor	O	1					2																									NA	NA	NA		
Operophtera brumata	W													2	2						2											NA	NA	NA		
Operophtera fagata	W																							2								NA	NA	NA		
Opigena polygona	O		2					1	2				2	2	2			2		2		1	1	2	1		2	2				NA	NA	NA	2	
Opisthograptis luteolata	W		2	2		2	2	2	2	3	2	1	2		2	2	3			2	1		2	3	3	2	2			1	2	NA	NA	NA	2	1
Orgyia antiqua	W						2				2									1		1			1		2		1			NA	NA	NA		
Orthosia cerasi	W				2	2	3		2		1	1	2	2	2	3	2	2	2	3	2	2	3	1	3	3	3	2	2	2	3	NA	NA	NA	2	3
Orthosia cruda	W		3	3	2	2	2	2	3		2	1	2	2	2	3	2	3	2	3	3	2	3	2	4	2	2	2	2	2	2	NA	NA	NA	2	3
Orthosia gothica	O		3	3	2	2	2	3	2	2		2	3	2	3	3	2	2	3	2	2	2	3	2	3	2	3	3	3	2	3	NA	NA	NA	2	2
Orthosia gracilis	O		3		2	2	2	2	2			1		2		2	1		1			1		2	2	2	2	2			2	NA	NA	NA	2	
Orthosia incerta	W		2		2	2	2	2	3	2		2	2		2	3	1		2	1		2	3	2	2	1	2	3	2		1	NA	NA	NA	2	2

Orthosia miniosa	W	1																1					2		1		1	2				NA	NA	NA	2	
Orthosia opima	O							1	3							2						2	3						1			NA	NA	NA		
Orthosia populeti	W	1	2					1						3	2						2			2		1	2					NA	NA	NA	2	
Otrhonama vittata	O	1																							1							NA	NA	NA		
Ourapteryx sambucaria	W		1		2		2	1	2	1	3	2	2	2	1	1	1				2	2	1	1		1	2	1		2		NA	NA	NA	2	
Pachetra sagittigera	O						1																									NA	NA	NA		
Panemeria tenebrata	O							1		1				1	1																	NA	NA	NA		
Panolis flammea	W		1	3	1	2	2			1	1	2	1	2	2		1	2			2		2			2	1		2	1	2	NA	NA	NA	3	
Panthea coenobita	W		1		2		2	1		1	2	2	1	2	2					1	2	2	1	3		1	2	2	1	2		NA	NA	NA	1	2
Paradarisa consonaria	W	1															1														1	NA	NA	NA		
Paradrina clavipalpis	O		1				2	1		2	2	2	1		2										2				2			NA	NA	NA		
Paradrina selini	O	1																							1							NA	NA	NA	1	
Parasemia plantaginis	O															1																NA	NA	NA		
Parastichtis suspecta	W										1																					NA	NA	NA		
Parastichtis ypsillon	W																							1								NA	NA	NA		
Parectropis similaria	W		2		1	1	2			2		1	2		2	1			2	2		1		2	1	2	2	2			1	NA	NA	NA		2
Pechipogo strigilata	W		2								2	1				1	1			2		1					2	2				NA	NA	NA		
Pelosia muscerda	W									1																						NA	NA	NA		
Pelurga comitata	O		1										1					1														NA	NA	NA		
Pennithera firmata	W			2			2					1			2							2			1			2	2		2	NA	NA	NA		
Penthophera morio	O																2						3		2							NA	NA	NA		
Peribatodes rhomboidaria	W		2				2	2	1	3	3	2	2	2	2		2	2	2	1	2	2	1	3	3	2	2	2	2		2	NA	NA	NA	2	3
Peribatodes secundaria	W						2			1		1									2				1						2	NA	NA	NA		
Peridea anceps	W		2					2		1			2		2	2	1		1	2	1	2				2	2	2		1	1	NA	NA	NA	2	2
Peridroma saucium	O	1						1																								NA	NA	NA		
Perizoma albulata	O										3								2	2					2	1						NA	NA	NA		
Perizoma alchemillata	W		2				1	2			3	2	2	2	2	1	1	2	2	2	2	1	1	2		1		1	2			NA	NA	NA		2
Perizoma bifaciata	O								1	3														1	2							NA	NA	NA		
Perizoma blandiata	O																		2	1												NA	NA	NA		
Perizoma flavofasciata	O		2					2			1	1								1					1							NA	NA	NA		
Petrophora chlorosata	W	1	1				1																									NA	NA	NA		1
Phaiogramma etruscaria	O																2															NA	NA	NA		
Phalera bucephala	W		2	2			1	1	1		2		2	2	1	1			2	1	2	1	1	1	1	1	2	1	2	1	2	NA	NA	NA	1	2
Pharmacis lupulina	O																2					3						1				NA	NA	NA		
Pheosia gnoma	W		1		1			1						1	2			2		2		1				2			1	1	1	NA	NA	NA	1	1
Pheosia tremula	W		2			1	2		1		3	1	1		2	2			2	2	1	1	1	2		2	1	1	2	1	1	NA	NA	NA	1	1
Philereme transversata	W							1			1						1					1	1					1	1			NA	NA	NA	2	
Philereme vetulata	W		2					1	3		3		1	1	1	1			2			1	1		1		2	1	2			NA	NA	NA	2	
Phlogophora meticulosa	O		2		1	1	2	1	1	2	3	2	2		1		1		2	2	2	1	1	2	3	2	2	2	2			NA	NA	NA	2	2
Phlogophora scita	W	1																						1								NA	NA	NA		
Photedes extrema	O	1														1						1										NA	NA	NA		
Photedes fluxa	O		1				2	1	1		2	1	1		1					1			1	1					1		3	NA	NA	NA		

Photedes morrisii	O										2										1									NA	NA	NA					
Phragmatobia fuliginosa	O		2	3	2	2	2	3	3	3	3	2	2	2	2	4	3	3	2	2	2	3	4	3	2	3	2	2	3	2	3	NA	NA	NA	2	3
Phragmatobia luctifera	O	1							1														1							2		NA	NA	NA			
Phyllodesma tremulifolium	W	1			1					1			2					1					1			1						NA	NA	NA			
Phymatopus hecta	O																	2						2								NA	NA	NA			
Phytometra viridaria	O																1															NA	NA	NA			
Plagodis dolabraria	W		2	2	2		1	2		2	1	1	2	1	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	3	1	2	NA	NA	NA	2	3
Plagodis pulveraria	W		1		2		2	2		3		1	2		2	2	1	2		1					2			2			2	NA	NA	NA		2
Plemyria rubiginata	W		2	2	2	1			1	2	1				1		1	1			2	1	1	2	1			2	2			NA	NA	NA	1	
Plusia festucae	O	1																1														NA	NA	NA			
Poecilocampa populi	W		2					2					2	3	2			2			2	2		3								NA	NA	NA			
Polia bombycina	O		2			2	1		2				1												1						2	NA	NA	NA			
Polia hepatica	O				1						2																					NA	NA	NA			
Polia nebulosa	O		3		2	1	1	2	2	3	1		3	2	2	2		2	2	2		2	1	2	3	2	1	2		2	2	NA	NA	NA		1	
Polychrysia moneta	O	1																														NA	NA	NA	1		
Polyploca ridens	W						1									2	1			2			2		3	2	2	1	1	1		NA	NA	NA	2	1	
Polypogon tentacularius	O		2		2	1	2	2	3	2	3	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2		2	2		3	NA	NA	NA	2	3	
Proserpinus proserpina	O	1									1			1		2														1		NA	NA	NA			
Protodeltote pygarga	O		2	2			2	2	1	3	2	2	2	2	2	1	2	2	2	2	2	3	2	4	2	2	2	4	2		1	NA	NA	NA	2	2	
Proxenus lepigone	O	1																1						1								NA	NA	NA			
Pseudeustrotia candidula	O		2			2		1		1			1	2	2			2	2	1	2			3	2	1	2	2				NA	NA	NA			
Pseudoips prasinanus	W		2	1	2	1	2	3	1	1	1	2	3	2	3		2	2	2	2	2	3		3	1	2	3	2	2	2	1	NA	NA	NA	2	2	
Pseudopanthera macularia	O						2		1	3		2		3		2	2			1	3	2	1	1	3						2	NA	NA	NA		2	
Pseudoterpna pruinata	O		1					2		2			2		2				2				2		2	2	1					NA	NA	NA			
Pterapherapteryx sexalata	W						1				1									2		2	1	2			2					NA	NA	NA			
Pterostoma palpinum	W		2	1	1	2	1	1	1		2	2	1	1	1	1	1	2	1	2		2	1	3	2	3	2	1	1	1	1	NA	NA	NA		1	
Ptilodon capucina	W		2		1		1	1			2	1	2		1	2			2	2	1	2			1	1		2	2	1	2	NA	NA	NA	1		
Ptilodon cucullina	W		2	2	1		1	1		1			2	2	1	2	2	2	2	1	2	2	1	3	2	2	2	2	2	1	1	NA	NA	NA	2	1	
Ptilophora plumigera	W							2			1			2	2						2	1										NA	NA	NA			
Pungeleria capreolaria	W		1										2						2										1			NA	NA	NA			
Pyrrhia umbra	O		2	2	1	2	1	2	2		2	1		2		2	1	1		1	2		1	2	1	1		1	2	1	1	NA	NA	NA	1		
Rebelia herrichiella	O										2						2								1							NA	NA	NA			
Rhinoprora chloerata	W													1		2												3				NA	NA	NA			
Rhinoprora rectangulata	W		2	1		1	1		2	2	2	1	2		2	1	1					2	2	2	2				2			NA	NA	NA	2		
Rhizedra lutosa	O										1													2								NA	NA	NA			
Rhodostrophia vibicaria	O		2				2					2	2	2				1							2			2	2			NA	NA	NA			
Rhyparia purpurata	O	1																							1			1				NA	NA	NA			
Rivula sericealis	O		2		2		2	2	3	2	3	2	2		2	2	2	3	2	2	2	3	3	4	3	3	2	4	3	1	2	NA	NA	NA	3	3	
Rusina ferruginea	O		2		2	2	1	1	2	2	2	1	1	1	2	2	1		2	2		2	2	3	2	1	2	3	2		3	NA	NA	NA			
Sabra harpagula	W		1	2	2	2	1		2	2	2		2	2	1	2	2	2	2	2	2			2	2	2	2	1	1	2	2	NA	NA	NA	2	2	
Saturnia pavoniella	W							1																			2					NA	NA	NA			
Saturnia pyri	W																1				1		2									NA	NA	NA	2		

Scoliopteryx libatrix	W		1	1	1	1			1		1									1					2		1	2		2		1	NA	NA	NA								
Scopula floslactata	O										1															1							NA	NA	NA								
Scopula immorata	O		2	1	2	2	1	3	2	3	3	2	3	2	3	2	1	2		2	2	2	3	3	3	2	3	2	2	2	2	NA	NA	NA	2							
Scopula immutata	O			1												2	1							2				2	2		1	NA	NA	NA	2							
Scopula incanata	O									1			1	1				2			1			2								NA	NA	NA								
Scopula marginepunctata	O										3																	1				NA	NA	NA								
Scopula nigropunctata	O		2		1				1	3	3				2	1	1	1	2	1			1	2	2			2	2		2	NA	NA	NA		1						
Scopula ornata	O		2	1		1			2		2	1	1	2	1	2		2		2	2		1	1	2		1	2	2	1	2	NA	NA	NA								
Scopula rubiginata	O		2							3	1		2		1					1				2	2	1	2					NA	NA	NA								
Scopula subpunctaria	O	1																					2									NA	NA	NA								
Scopula ternata	O	1					1																					1				NA	NA	NA								
Scopula virgulata	O		1					2	3		3			2				3		3	3		2	2	2		1	2				NA	NA	NA	3							
Scotopteryx bipunctaria	O								2						1										1							NA	NA	NA								
Scotopteryx chenopodiata	O		2		2			2	2	1	3		2	1	2	3	2	2	2	3		3	3	3	3	3	2	3	3	1	3	NA	NA	NA	2	3						
Scotopteryx mucronata	O															2								2	1							NA	NA	NA								
Selenia dentaria	W		2		2	2	2	2	2	2	2	1	2	1		1	2		2	1	1	1	2	2	2	2	2	2	2	1		NA	NA	NA	2							
Selenia lunularia	W			1				2		1	2		2		1	1		2		1	2		1	2	2				1	1		NA	NA	NA	1							
Selenia tetralunaria	W		1	1	2	2	1	1			1	1	1	1	1	2			2	2		2	2	2			2			2	2	NA	NA	NA	2	2						
Sideridis rivularis	O															1				1				2				1			1	NA	NA	NA	1							
Simplicia rectalis	W	1	1															1										1				NA	NA	NA								
Siona lineata	O		2	1	2	3	2	2	3	3	3	2	3		2	3	2		2	3		3	3	3	3	2	2	2	3	2	3	NA	NA	NA	2	1						
Smerinthus ocellatus	W		2		2	2	1		1		1	1										1	1				1					NA	NA	NA								
Spatalia argentina	W															1	2									1						NA	NA	NA	1							
Sphinx ligustri	W		1				1	1	2	1	1	1	2	1	1		1	2	1	2		2	2	1	2	1	1			1		NA	NA	NA	2	2						
Sphinx pinastri	W		2	2	2	1	2	2	2	2	2	2	1	2	1	2	1	2	2	2	2	2	1	2	3	2	2	2	2	2	3	NA	NA	NA	2	2						
Spilosoma lubricipeda	O		2	2	2	3	2	2	2	2	1	1	2	2	2	2	2	3	3	2	2	3	3	3	2	2	2	3	2	2	1	NA	NA	NA	2	2						
Spilosoma luteum	O		1			2	2	1	2	2	2	2	2		1	1	1	1	2	1		2	1	3	1		2	2	2	2		NA	NA	NA		1						
Spodoptera exigua	O	1																														NA	NA	NA	1							
Stauropus fagi	W		2	2	2	2	1	2		2	2	1	2	2	2	2	2	2	3	2	2	2	1	3	2	3	2	2	2	2	2	NA	NA	NA	2	1						
Stegania cararia	W	1	2		2			2				1	2		1				1			1	1	1							NA	NA	NA	1							
Stegania dilectaria	W	1								2	1												1		2							NA	NA	NA								
Sterrhopterix fusca	W								1		1																	2				NA	NA	NA	2							
Tethea ocularis	W																							2			2					NA	NA	NA								
Tethea or	W		3	1	2	2	2	2		1	2	1	3	2	2	1	2	2	2	2	2	1	1	2	2	3	2	2	2	1	2	NA	NA	NA	2	2						
Tetheella fluctuosa	W		1		2		2					2			2		1	2	1	3	2		2			1						NA	NA	NA	1	2						
Thalera fimbrialis	O		2		1	1		1			1		2	2	1		1	2			2	1	1	2		1		2	2		1	NA	NA	NA								
Thalpophila matura	O		2		2	2	2		1	3	3	2	2	3	2	3		2		2	2	2	2	2	3	2	2	2	2		3	NA	NA	NA	2							
Thera britannica	W	1					2																									NA	NA	NA								
Thera juniperata	W														2																	NA	NA	NA								
Thera obeliscata	W		2				2			2		1		1	2	1	2	1						1				2	1		1	NA	NA	NA	1							
Thera variata	W						2		2	1	1	1	2	2	2	2		1	2	2	2	2		3	1	2	1	3	3		2	NA	NA	NA	2	2						
Thera vetustata	W	1					1																									NA	NA	NA								

Thetidia smaragdaria	O			1							2		1									1										NA	NA	NA		
Tholera cespitis	O		3	1	2	2	2		2		2	2		2	1	2		2	2	2	3				2		2	3	3		3	NA	NA	NA		2
Tholera decimalis	O		2		2	2	3	2	2	2	3	2	1	2	2	2	2	2	2	2	3	2	2		3	2	2	3	2		2	NA	NA	NA		2
Thyatira batis	W		2	1	2	2	2	2	2	2	3	2	2	2	2	1	2	2	2	2	2	2	1	3	2	2	2	2	3	2	1	NA	NA	NA	2	2
Tiliacea aurago	W		3	1	2	2	2	3	2	2	3	2	2	4	1		1	2	2	2	2	3	2	2	2	3	2	2	2	2		NA	NA	NA	2	3
Tiliacea citrago	W		1		1					2	1		1	2	1			2	1	2	2		1			2	2	1	2	1		NA	NA	NA	2	
Timandra comae	O				2	2	2		2	2	2	2	1				2	1	2	2		1	3	3	2		2	2	2	1		NA	NA	NA		2
Trachea atriplicis	O		2	1	1	2	1	1	2	1	2	1	2	2	2	1		1	2		2	1	2	2	1	1	2	2	2	2	1	NA	NA	NA	1	2
Trichiura crataegi	W	1								1						2	1		2						1						1	NA	NA	NA		
Trichopteryx carpinata	W															2			1	2		1				2	2		2		1	NA	NA	NA		1
Trichopteryx polycommata	W	1					2		1			2													1							NA	NA	NA		
Triodia sylvina	O		2		2	3	2	2	1	2	2	2	1	2			2		2		2				3		1		2		2	NA	NA	NA		3
Triphosa dubitata	W																										1		1			NA	NA	NA		
Trisateles emortualis	W		2					1		1			2		2	1	1			2		2						2	2			NA	NA	NA	1	
Tyria jacobaeae	O					2																	1									NA	NA	NA		
Tyta luctuosa	O		2			2			2	2	3		2	2				2				1	1	2	2	2	2		2			NA	NA	NA	2	
Valeria oleagina	W	1																1					2			1						NA	NA	NA	2	
Venusia blomeri	W	1																							1							NA	NA	NA		
Watsonalla binaria	W		2	1	1	1	1	2		2	2	1	2	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	1		NA	NA	NA	2	2
Watsonalla cultraria	W		2		2	1	2	2		1	2	2	2	3	2	2		2	3	2	2	3	2	2	1	2	2	2	2	1	2	NA	NA	NA	2	2
Xanthia icteritia	O		2		2	2	2	2	2	1		3	2	2	1	1	1	2	2	2	2	2	2	1	2	3	2	2	2	2	2	NA	NA	NA	2	2
Xanthia ocellaris	O										1							2			2											NA	NA	NA		
Xanthia togata	O		2					1					1	2		1				1	2	1		3	1	1	1	2	2		2	NA	NA	NA		3
Xanthorhoe biriviata	W		2		2	2	2	2			1	2	2	2				2	1		2	2	2						2			NA	NA	NA		
Xanthorhoe designata	W				1						1					1									1				2			NA	NA	NA	1	
Xanthorhoe ferrugata	O		2		1		2	2	2	2	2	1	3	2	2	2	2	2		1	2		2		2			2	2			NA	NA	NA	2	
Xanthorhoe fluctuata	W		2				1	2	1	1		2	2		2	1	1	2		2			1		2			3	1		1	NA	NA	NA		
Xanthorhoe montanata	O			1	1			2					3	2	2	2		2		2		2		2			1		2			NA	NA	NA		1
Xanthorhoe quadrifasciata	O		2	1			2		1		2	1		2				2			2	1		2	1			2	2			NA	NA	NA	1	
Xanthorhoe spadicearia	O		2			1	2	2	2	2	2	3	2	2	1	3	2	2	2	3	2	2	2	3	3	3	1	2	2	2	2	NA	NA	NA	2	3
Xestia baja	O		2		1		2	1	1	2	3	2	2		2	3	2		2			2	2	3	2	2	2	3	2		3	NA	NA	NA	1	2
Xestia c-nigrum	O		3	1	2	2	2	3	3	5	5	2	4	3	3	3	2	3	2	3	3	3	3	4	5	4	3	4	3	2	2	NA	NA	NA	3	3
Xestia ditrapezium	O		1				2	2	2	2	2	2	2	2	1	3		2	2	2	2	3	1	3		2	2		1		2	NA	NA	NA	2	1
Xestia sexstrigata	O		1		2	1			2	2	2					2			2					2	1				2	2	3	NA	NA	NA	1	
Xestia stigmatica	O		2		2		1	2	1	1	1		2	2		2		1		2	2	2	1	3	2	2	2	3	2	1	2	NA	NA	NA	1	
Xestia triangulum	O		1		2	2	2	2	2	2	3	1	2	2	1	2	2	2	2		2	2	1	3	2		1				2	NA	NA	NA		
Xestia xanthographa	O		2			2	2		3	2	3	2		2	2		2	2	2	2	3	2	2	2	2	1	2	3	3		3	NA	NA	NA	2	2
Xylena exsoleta	O	1																								1			1			NA	NA	NA		
Xylena vetusta	O													1						1												NA	NA	NA		
Zanclognatha tarsipennalis	W							2					2		1					1					2	1		2	1		1	NA	NA	NA		
Zeuzera pyrina	W		2	2	2			1	2		1	1	1	1	2		1		2	1		1	1	1	1	1	1	1	1			NA	NA	NA	1	

Table S9 Orthopteran dataset. Species abundances were expressed on an ordinal scale as follows: 1 – 1–3 specimens; 2 – rare, up to about 10 specimens; 3 – common, tens of specimens.

ID site			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Species	**Open-country (O) /Woodland (W)**	**Regionally Important Species**	Starohrozenkovský lom	Kladná	U Petrůvky	Štítná – stráň nad dráhou	Ploščiny	Záhumenice	Bylnice – Na stráži	Suchov – nad Ostrožankou	Nová hora	Bílé potoky	Podhradské louky	Mechnáčky	Cestiska	Kaňoury	Javorník – pod Hradiskem	Žerotín	Hutě	V Krátkých	Kútky	U Megovky	Podlučí	Končiny	Drahy	Machová	Rybnické údolí pod Machovou	Přední louky	Dolnoněmčanské louky	Paseky u Nedašovy Lhoty	Sidonie – pastvina na hranici	Javorina	Jamy u Březové	Lopenické sedlo	Skleněný vrch	Hrnčárky
Barbitistes constrictus	W			1		1	1			1	1				2		3			3		1						3	1	3					NA
Calliptamus italicus	O	1													1																				NA
Chorthippus albomarginatus	O				3								1	1							3			3											NA
Chorthippus apricarius	O		2	3	3	3	3		3	3	3	1	3	3		2		3	2	2					2	3				2			2		NA
Chorthippus biguttulus	O		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		2	3	3	3	3	3	3	3	3	3	3	3	3	NA
Chorthippus brunneus	O		3						1						3			3			3									2					NA
Chorthippus dorsatus	O		3	3		3	2	3	2	3	3		3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3			3	3	3	NA
Chorthippus mollis	O																	3																2	NA
Chorthippus montanus	O				3			3	1	2	1		1	1			2		3		2			2								1			NA
Chorthippus parallelus	O		3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	NA
Chorthippus vagans	O						1																													NA
Chrysochraon dispar	O		2	1	3	1		3		2	2	1	1	1	3	3	3		2	3	3		3	3	2	3	3	3	3	3	3			3	3	NA
Conocephalus fuscus	O													1							2		3								1		3			NA
Decticus verrucivorus	O		2				3		2		2	1	3	2		3					3	1	1	3	1		1			3	2			2		NA
Euchorthippus declivus	O	1											1										1													NA
Euthystira brachyptera	O		3	3	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	NA
Gomphocerippus rufus	O						3			3	3	2	3	3	3	3	2	3			3	2	3	3			3		3	2	2			2	3	NA
Gryllus campestris	O	1	3	2	3	3			3	2	3		2	2		2	2		2		3		1		3			1		1	1		1	1		NA
Isophya kraussii	O		2				2	3		1	2	1	2	2	3	3		1	3	3	1	1		3	1	3		1	3	2	1			1		NA
Isophya pienensis	O	1																													2					NA
Leptophyes albovittata	O		3	2	3	2		3	3	3	3		3	1	3	3	3	3	3			3	3	3	3	3	3	3					2	1	3	NA
Meconema thalassinum	W		2		3	3	2	3		1	1	1		1	3		3	3	1	2	3		1		1	3	3	3	3				1		3	NA
Metrioptera bicolor	O		3			3	2		3	3	3	1	2		3		3	3		3	3		3		2			2							3	NA
Metrioptera brachyptera	O									2												3														NA

Metrioptera roeselii	O		3	3	3	3	3	3	3	3	3	3	3	2	3	3	3		3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	NA
Myrmecophilus acervorum	O		1																																NA
Nemobius sylvestris	W			3									2								3			3										3	NA
Oecanthus pellucens	O								1														1		1										NA
Oedipoda caerulescens	O	1					3														2														NA
Omocestus rufipes	O	1				1																													NA
Omocestus viridulus	O				3		3	3		2	3	2		3					2		3	2					3	3		3	3		3		NA
Phaneroptera falcata	O		3	1	3	2			2	3	3				3	1	3	3		3			3	3	3	3		3			1				2	NA
Pholidoptera griseoaptera	O		3	1	3	2	2	3	2	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2	3	2	3	3	3	3	3	3	3	3	3	3	NA
Platycleis albopunctata grisea	O	1	3			1	1		1							1		3			3															NA
Polysarcus denticauda	O	1								1				1		3	1			3	1			2		3	2			1				2		NA
Pseudopodisma nagyi	O	1																									1									NA
Psophus stridulus	O	1														3														2						NA
Stenobothrus crassipes	O													1				2																	3	NA
Stenobothrus lineatus	O			3		2	1		3	3	3	1	2	2	3	3			3			3	3	3		2		3		2	2	1				3	NA
Tetrix bipunctata	O	1					1					1				2				1																NA
Tetrix subulata	O																		2															2		NA
Tetrix tenuicornis	O		3	3	3	2	2	3	2			2			3	3	2	3			3	2	3	3		3	3	3	3	3	3			3	3	NA
Tetrix undulata	O		3								2			2																	2				NA
Tettigonia cantans	O		2	1	3			3		1	2	3	1	1		3			2	3	1	3		3		3	3	3	3	3	3		1	1	3	NA
Tettigonia viridissima	O		2			2			2	2		1		1	3		3	3	2	3	3		3	3	1	3	3	3				1			3	NA

Table S10 Ground beetle dataset. Species abundances were expressed on an ordinal scale as follow: 1 – 1 specimen; 2 – 2–10 specimens; 3 – 11–50 specimens; 4 – 51–100 specimens; 5 – >100 specimens.

ID site			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
Species	**Open-country (O) /Woodland (W)**	**Regionally Important Species**	Starohrozenkovský lom	Kladná	U Petrůvky	Štítná – stráň nad dráhou	Ploščiny	Záhumenice	Bylnice – Na stráži	Suchov – nad Ostrožankou	Nová hora	Bílé potoky	Podhradské louky	Mechnáčky	Cestiska	Kaňoury	Javorník – pod Hradiskem	Žerotín	Hutě	V Krátkých	Kútky	U Megovky	Podlučí	Končiny	Drahy	Machová	Rybnické údolí pod Machovou	Přední louky	Dolnoměmčanské louky	Paseky u Nedašovy Lhoty	Sidonie – pastvina na hranici	Javorina	Jamy u Březové	Lopenické sedlo	Skleněný vrch	Hrnčárky
Abax carinatus	W										2		2	2	2				2											NA	NA					NA
Abax ovalis	W		2					2			2						2		3	2		2		2			2		2	NA	NA					NA
Abax parallelepipedus	W		2	1	1	2		3		2	2		2	3	1	3	2	2	3	3	3		2	2	3	2	2	3	3	NA	NA		3	3	2	NA
Abax parallelus	W		1	2	3			3	2	2	2			2		3	2	2	3	2	2		2	2		2	2	2		NA	NA		2			NA
Abax schueppeli	W	1	2					2											2				1	2			1		1	NA	NA		2			NA
Agonum viduum	O																					1								NA	NA					NA
Amara aenea	O			1			2																2							NA	NA		3			NA
Amara aulica	O																								2					NA	NA		1			NA
Amara convexior	O				1			2						2		1									1	2			2	NA	NA			1		NA
Amara curta	O																								1					NA	NA					NA
Amara equestris	O					2	3		2			2												2	2			1	1	NA	NA					NA
Amara lunicollis	O				2			2					2								2								1	NA	NA	2				NA
Amara montivaga	O																		2											NA	NA					NA
Amara ovata	O						2	2		1																				NA	NA					NA
Amara similata	O						2																		2					NA	NA					NA
Anchomenus dorsalis	O		1	1			2																		2			2		NA	NA					NA
Aptinus bombarda	W	1		3	3								2			2	2									1				NA	NA		2		4	NA
Bembidion lampros	O																												1	NA	NA					NA
Bembidion mannerheimi	O																									2				NA	NA					NA
Brachinus crepitans	O						2		1									1												NA	NA					NA
Calathus fuscipes	O		2	2		3		4	3	2	3			2	2		2	3			3		2	2	3	2		3		NA	NA	3	2		3	NA
Calathus melanocephalus	O			1				1																						NA	NA	2				NA
Callistus lunatus	O	1																										2		NA	NA					NA

Carabus cancellatus	O	1							2							1	2								2	2		2	NA	NA					NA
Carabus convexus	O	1			2		1					1			2						1	1		1	2				NA	NA					NA
Carabus coriaceus	O		2	2	2	2		2	3		1	2	2	2	2	2	2	2	2	2	2	2		3	2		2	2	NA	NA	2	2	2	2	NA
Carabus granulatus	O																												NA	NA		2			NA
Carabus hortensis	W		2	2	2					2						2	1		3	2	2	2			2			2	NA	NA		2	3	2	NA
Carabus intricatus	W		2	1	1																								NA	NA					NA
Carabus linnaei	W																		2	2									NA	NA	1		4		NA
Carabus nemoralis	W			2						2							1									2		2	NA	NA		2			NA
Carabus obsoletus	W	1																											NA	NA				1	NA
Carabus scheidleri	O		2		3	2	2	3		3		3	2	2	2	2	2	3	2	2			3	2		2	2	2	3	NA	NA	2	3	3	3	NA
Carabus ullrichii	O		2			2		2	2	4	2	2	2	3		2	2		2		2		2	3	2	2	3	3	2	NA	NA	1	3		2	NA
Carabus variolosus	W	1						2														2						1	NA	NA					NA
Carabus violaceus	O		4	3	3	2	3	4	2	2	2	2	3	3	2	2	2	3	4	4	2	3	3	2		3	2	2	3	NA	NA	3	4	4	3	NA
Cicindela campestris	O		2	2	1	2	2	2	3												2		2		2	2		2	3	NA	NA				2	NA
Cychrus attenuatus	W	1		1	1														2										NA	NA					NA
Cychrus caraboides	W			1				1											2	2		2							NA	NA		2	2		NA
Cylindera germanica	O	1	2						3					2							2								NA	NA					NA
Harpalus afinis	O			2																									NA	NA					NA
Harpalus caspius roubali	O	1							2		2															2			NA	NA					NA
Harpalus latus	O				2		2								2														NA	NA	2				NA
Harpalus marginellus	O																									1			NA	NA					NA
Harpalus rubripes	O		2						1			2	2														2	2	NA	NA					NA
Lebia cruxminor	O	1	1																									1	NA	NA					NA
Leistus ferrugineus	O			1	1		2	1		2		1					2												NA	NA					NA
Leistus rufomarginatus	W																					1							NA	NA			2	2	NA
Licinus depressus	O	1							1																	1			NA	NA					NA
Limodromus assimilis	W		2															3	2		2								NA	NA		2	2	2	NA
Molops piceus	W			1	3		1	2				2		2			1			2				2		2	2	2		NA	NA					NA
Nebria brevicollis	O		2			2	2	3			2	2			1						3			3					3	NA	NA		2	3	2	NA
Notiophilus palustris	O																1												NA	NA					NA
Ophonus azureus	O		1																										NA	NA					NA
Ophonus stictus	O	1																2											NA	NA					NA
Panagaeus bipustulatus	O	1				1			2									2			1						2	1	NA	NA					NA
Patrobus atrorufus	W																					2							NA	NA					NA
Poecilus cupreus	O				3	3	2	2	3		2	2	3	3		3		2		1	2			3	3	2	2		2	NA	NA	3				NA
Poecilus versicolor	O		2		3			3		3			3			3					3			2		2	2	3	3	NA	NA	3		3		NA

Pseudoophonus rufipes	O			1			2	2		2			2	2				2		1	2		2	3	3	3	2		2	NA	NA	3	2	2	3	NA
Pterostichus burmeisteri	W							2											2	3		2							NA	NA		2	3	2	NA
Pterostichus foveolatus	W																												NA	NA			2		NA
Pterostichus incommodus	O	1																2											NA	NA					NA
Pterostichus macer	O	1		1																									NA	NA		2			NA
Pterostichus melanarius	O		2					3					2	3					3			2			2			3	NA	NA		3	2		NA
Pterostichus melas	O				2	2	2				3	1		2	1									2	2	2		2	NA	NA					NA
Pterostichus niger	O			2							2	2		2				3			3							NA	NA	3	2			NA
Pterostichus nigrita	O																				2								NA	NA					NA
Pterostichus oblongopunctatus	W			2															1										NA	NA	3		2		NA
Pterostichus ovoideus	O				1		1	2					1							2	1		2	2		1	1		NA	NA					NA
Pterostichus vernalis	O												2																NA	NA					NA

Table S11 Variation partitioning of the effects of management, climate and landscape context on species richness of five taxa based on GLMs. All values are percentage of adjusted explained deviation (D^2); zero values indicate zero or negative adjusted D^2. Statistically significant results are given in bold (** < 0.01; * < 0.05; ° < 0.1). OCS = open-country species; RIOCS = regionally important open-country species.

	Plants	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
	OCS/RIOCS	**OCS/RIOCS**	**OCS/RIOCS**	**OCS/RIOCS**	**OCS/RIOCS**
Management	**14.2°/22.5***	**26.1***/0.3	11.4/0	0.7/0	0/0
Climate	0.8/7.0	0/0.8	0/4.0	**25.3***/7.7	0/0
Landscape context	0/0	3.7/0	0/0	0/0	5.0/0
(Management ∩ Landscape context) | Climate	2.7/2.1	0/0	3.7/5.0	0/4.7	0/3.0
(Management ∩ Climate) | Landscape context	3.8/7.3	0/0.2	4.8/6.9	0/11.5	0/9.0
(Climate ∩ Landscape context) | Management	0/0	0/1.6	0.4/4.6	4.9/2.4	5.3/1.3
Management ∩ Climate ∩ Landscape context	0.8/0	4.5/2.8	0/0	2.4/0	4.1/0
Total explained variation	17.0/27.5	7.5/0	0/0	18.2/0	0/0

Table S12 Adjusted explained deviation (D^2) from GLMs of the effect of management practices on species richness for open-country species and open-country species of regionally important species only in individual taxa. All values are in percentage of adjusted explained deviation (D^2), zero value indicates zero or negative adjusted D^2. Signs in square brackets come from the corresponding regression coefficients. Statistically significant results are in bold (** < 0.01; * < 0.05; ° < 0.1). Gross effects are calculated after partialling out effects of climate and landscape context only; pure effects after partialling out effects of climate, landscape context and other management practices. NT = not tested due to non-significant effect of management (Table M.1).

Species richness – open-country species					
Management	**Plants**	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure
Mowing	**[+]11.1***/[+]0	[+]0/[-]6.1	NT	NT	NT
Grazing	[-]3.3/[-]0	[-]0/**[-]7.7°**	NT	NT	NT
Abandonment	[-]0/[-]0	[+]0/[-]7.3	NT	NT	NT
Mixed	**[+]18.7**/[+]9.7°**	**[+]25.9**/[+]36.9****	NT	NT	NT
Species richness – regionally important open-country species					
Mowing	**[+]20.0****/[+]0	NT	NT	NT	NT
Grazing	**[-]13.8***/[-]0	NT	NT	NT	NT
Abandonment	[+]0/[-]0	NT	NT	NT	NT
Mixed	**[+]17.0***/[+]3.5	NT	NT	NT	NT

Table S13 Variation partitioning based on RDAs of open-country species composition of each taxon explained by three groups of environmental variables. All values are percentage of adjusted explained variation (R^2). Statistically significant results are given in bold (*** < 0.001; ** < 0.01; * < 0.05; ° < 0.1; 9999 permutations).

	Plants	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
Management	**3.9***	0	2.9	0.9	0
Climate	**3.0°**	0	2.2	**8.1****	0
Landscape context	2.5	0	0	0.7	2.1
(Management ∩ Landscape context) | Climate	1.4	0.8	0	1.2	<0.1
(Management ∩ Climate) | Landscape context	0.3	1.0	0	0.2	0.1
(Climate ∩ Landscape context) | Management	0.6	1.6	0.2	5.7	0.9
Management ∩ Climate ∩ Landscape context	0	0	0.7	0.4	1.6
Total explained variation	**10.7*****	0	2.1	**16.3*****	1.9

Table S14 Adjusted explained variation (R^2) based on RDAs of all species composition of each taxon. All values are percentages. Statistically significant results are given in bold (** < 0.01; * < 0.05; 9999 permutations). Gross effects are calculated after partialling out effects of climate and landscape context only; pure effects after partialling out effects of climate, landscape context and other management practices. NT = not tested due to non-significant effect of management (Appendix L.1).

Management	**Plants**	**Butterflies**	**Moths**	**Orthopterans**	**Ground beetles**
	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure	Gross/Pure
Mowing	**3.7****/0.5	NT	NT	NT	NT
Grazing	**2.3***/0	NT	NT	NT	NT
Abandonment	0/0	NT	NT	NT	NT
Mixed management	**2.2***/1.0	NT	NT	NT	NT

Table S15 Adjusted explained variation (R^2) based on RDAs of all species composition of ground beetles. All values are percentages. Statistically significant results are given in bold (* < 0.05; 9999 permutations). GE = gross effect (climate and management types as covariables); PE = pure effect (other management types, climate and landscape context variables as covariables).

Landscape context	**Ground beetles**
	Gross/Pure
Grassland area percentage	1.5/0
Habitat heterogeneity	**2.7***/**4.0***
Cover of woody species	0.6/0.3
Shannon diversity index	1.4/1.3

Table S16 Results of RDAs of species composition considering the gross effect of mowing on all species of plants. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S1).

Mowing		
Plants all species	***Regr. Coef.***	***Effect***
Viola canina	0.6296	Positive
Rhinanthus minor	0.5322	Positive
Bromus erectus	0.4866	Positive
Primula veris	0.4786	Positive
Carex montana	0.4520	Positive
Traunsteinera globosa	0.4463	Positive
Molinia arundinacea	0.4453	Positive
Trifolium montanum	0.4286	Positive
Sanguisorba officinalis	0.4241	Positive
Tragopogon orientalis	0.4179	Positive
Silene nutans	0.4151	Positive
Carex caryophyllea	0.4069	Positive
Knautia arvensis agg.	0.4031	Positive
Hypochaeris maculata	0.4024	Positive
Calamagrostis epigejos	-0.6355	Negative
Hypochaeris radicata	-0.4844	Negative
Achillea millefolium agg.	-0.4698	Negative
Carlina vulgaris agg.	-0.4252	Negative
Tanacetum vulgare	-0.4071	Negative
Verbascum sp.	-0.3980	Negative

Figure S1 Results of RDAs of species composition considering the gross effect of mowing on all species of plants.

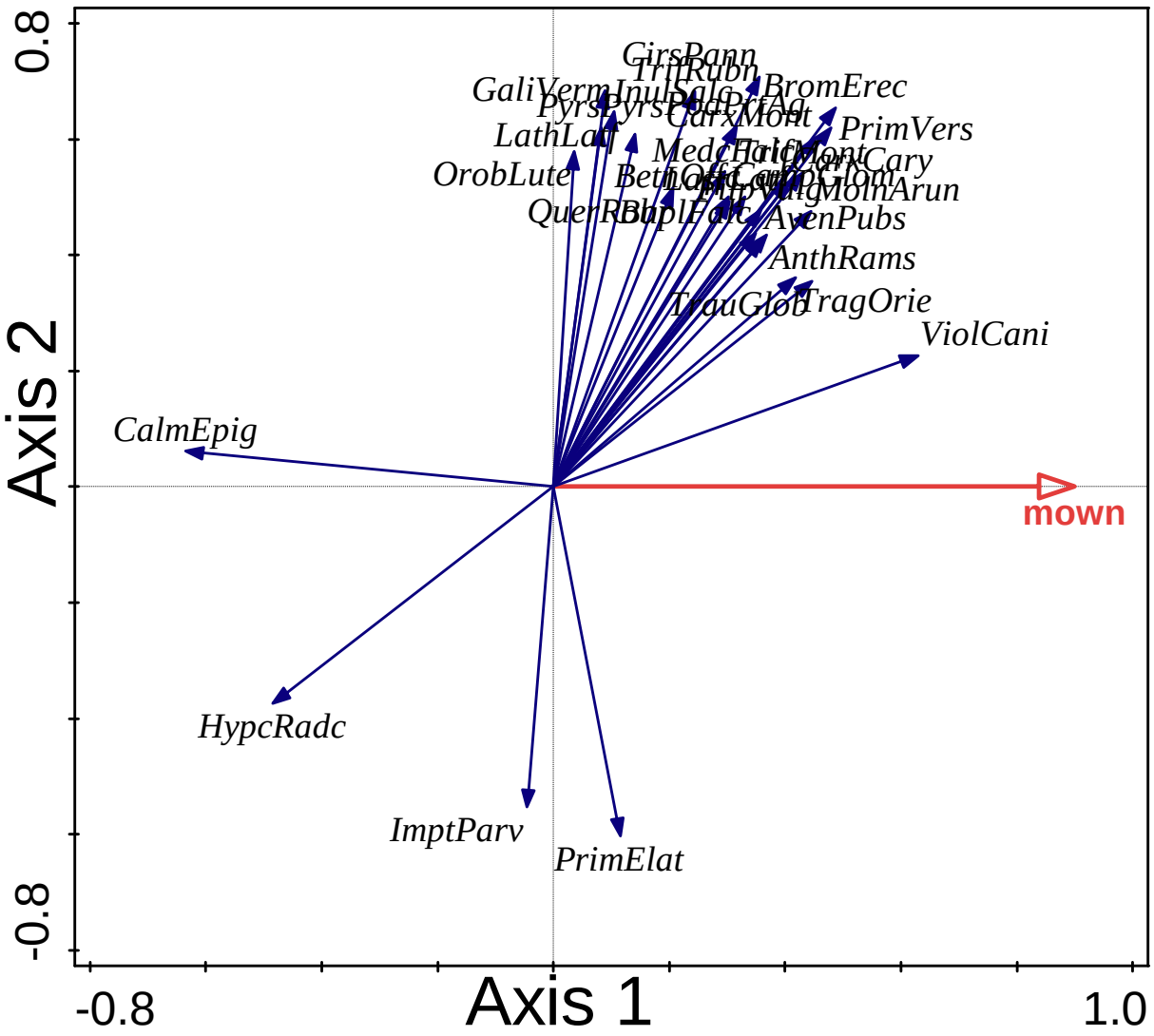


Table S17 Results of RDAs of species composition considering the gross effect of grazing on all species of plants. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S2).

Grazing		
Plants all species	***Regr. Coef.***	***Effect***
Carduus acanthoides	0.5924	Positive
Thlaspi perfoliatum	0.5870	Positive
Sisymbrium officinale	0.5600	Positive
Geranium columbinum	0.5541	Positive
Myosotis sylvatica	0.5470	Positive
Malva neglecta	0.5312	Positive
Odontites vernus	0.5312	Positive
Persicaria mitis	0.5312	Positive
Lapsana communis	0.5018	Positive
Arabidopsis thaliana	0.4923	Positive
Selinum carvifolia	0.4667	Positive
Anagallis arvensis	0.4485	Positive
Pilosella officinarum	0.4465	Positive
Eryngium campestre	0.4164	Positive
Festuca rubra	0.4088	Positive
Achillea millefolium agg.	0.4037	Positive
Galium intermedium	0.3988	Positive
Leucanthemum vulgare agg.	-0.4672	Negative
Viola canina	-0.4380	Negative
Valeriana officinalis agg.	-0.4020	Negative

Figure S2 Results of RDAs of species composition considering the gross effect of grazing on all species of plants.

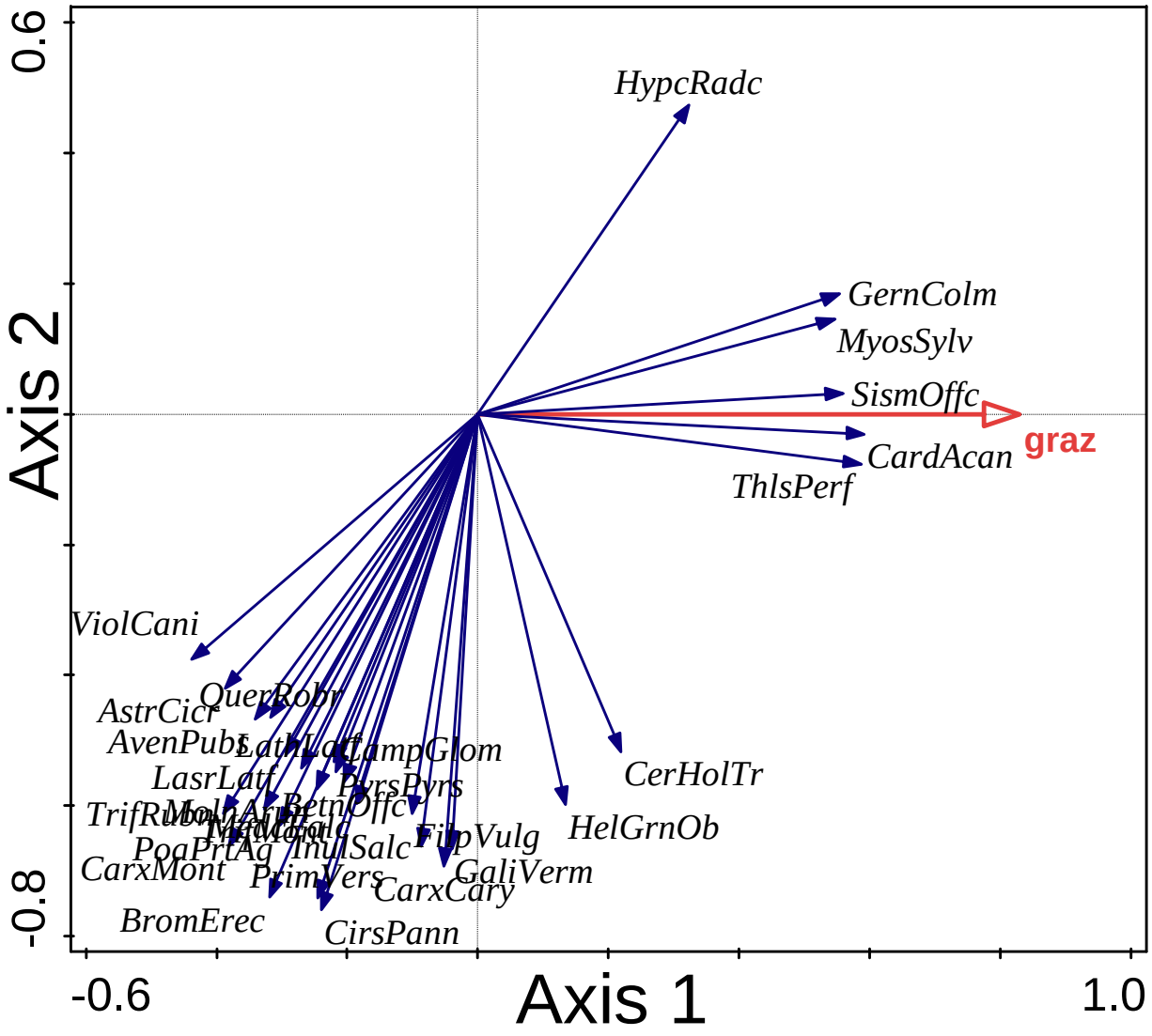


Table S18 Results of RDAs of species composition considering the gross effect of mixed management on all species of plants. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S3).

Mixed management		
Plants all species	***Regr. Coef.***	***Effect***
Anthericum ramosum	0.5794	Positive
Asperula cynanchica	0.4914	Positive
Polygonum aviculare agg.	0.4808	Positive
Bromus erectus	0.4583	Positive
Bupleurum falcatum	0.4581	Positive
Bromus inermis	0.4406	Positive
Viburnum lantana	0.4310	Positive
Veronica teucrium	0.4303	Positive
Pyrus pyraster	0.4263	Positive
Sinapis arvensis	0.4181	Positive
Heracleum sphondylium	0.4101	Positive
Anthyllis vulneraria	0.3994	Positive
Seseli annuum	0.3974	Positive
Primula veris	0.3970	Positive
Inula ensifolia	0.3941	Positive
Erigeron acris agg.	0.3905	Positive
Arabis hirsuta	0.3864	Positive
Rhamnus cathartica	0.3801	Positive
Hypochaeris radicata	-0.5407	Negative
Festuca rubra	-0.3981	Negative

Figure S3 Results of RDAs of species composition considering the gross effect of mixed management on all species of plants.

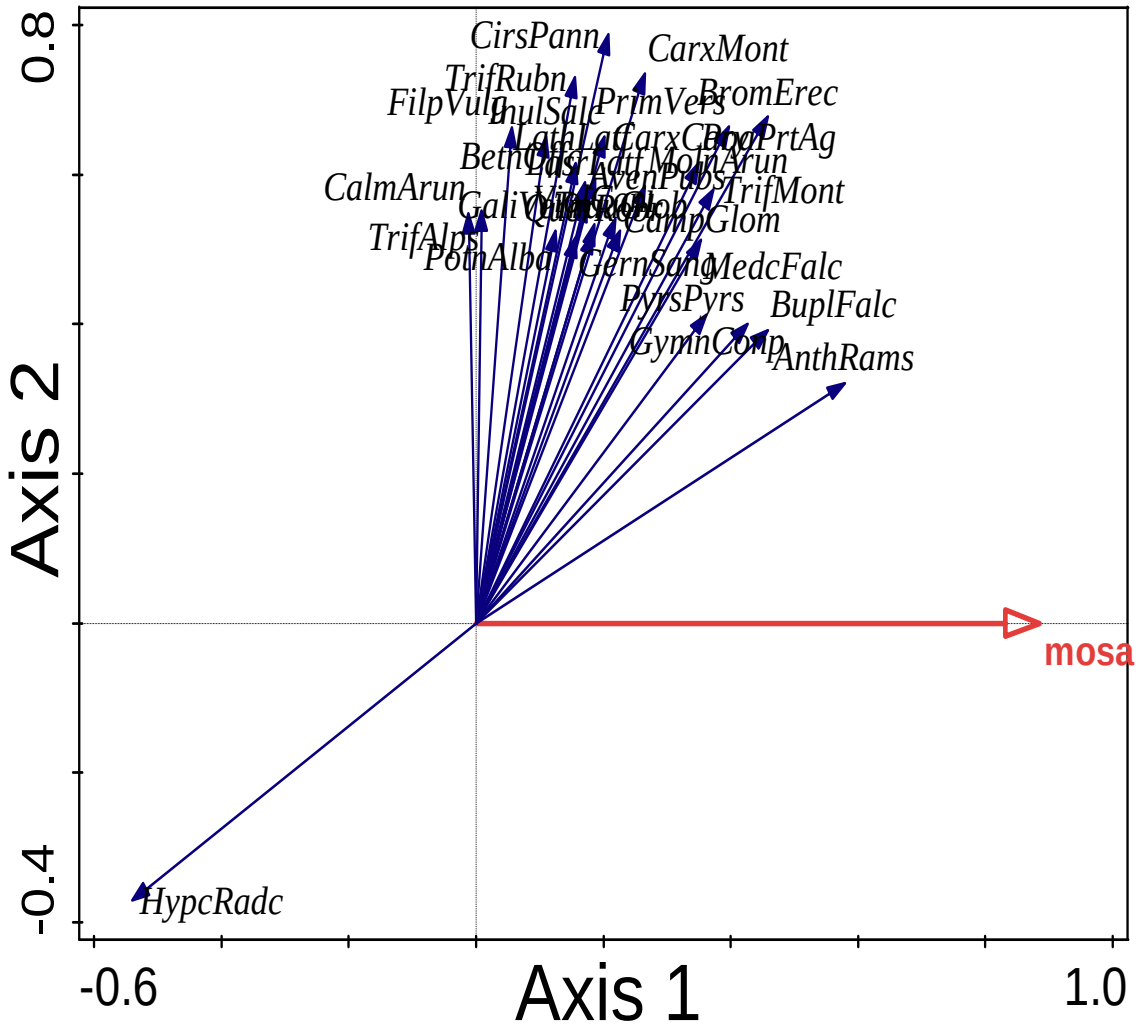
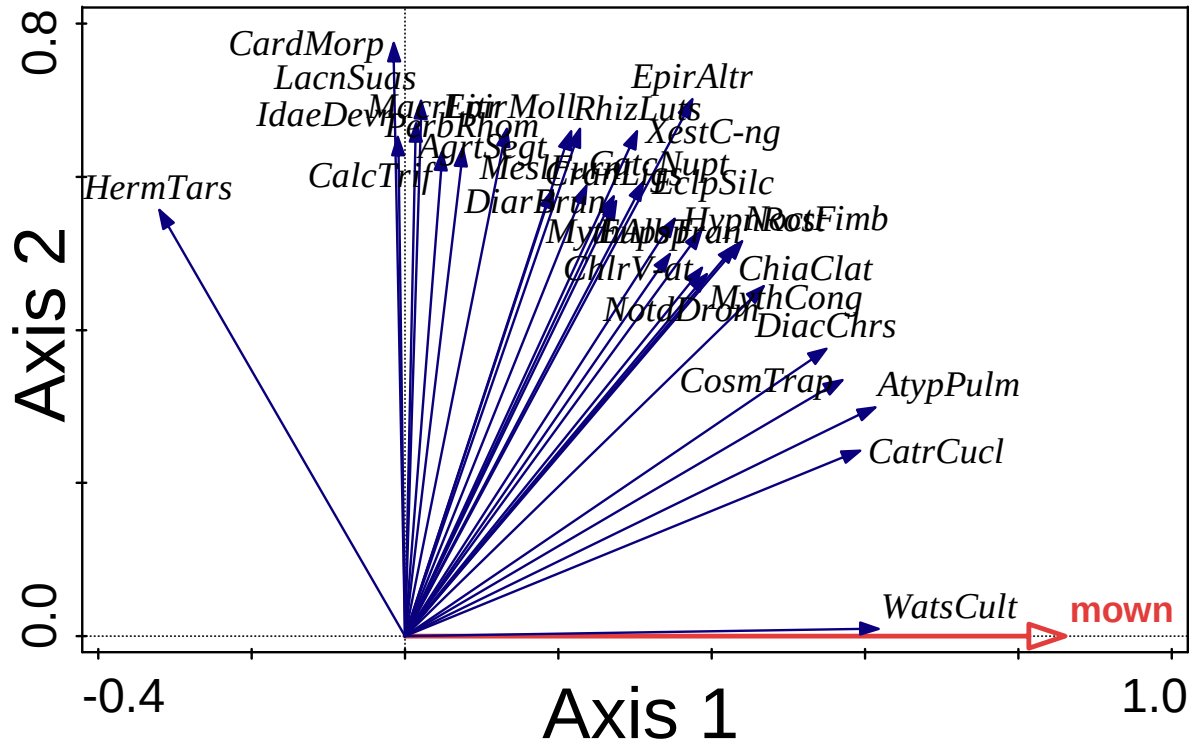


Table S19 Results of RDAs of species composition considering the gross effect of mowing on all species of moths. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S4).

Mowing		
Moths all species	***Regr. Coef.***	***Effect***
Watsonalla cultraria	0.6175	Positive
Atypha pulmonaris	0.6138	Positive
Catarhoe cuculata	0.5935	Positive
Cosmia trapezina	0.5701	Positive
Diachrysia chrysitis	0.5499	Positive
Perizoma alchemillata	0.5272	Positive
Drymonia querna	0.5039	Positive
Panthea coenobita	0.4798	Positive
Noctua orbona	0.4764	Positive
Arctornis l-nigrum	0.4744	Positive
Trachea atriplicis	0.4702	Positive
Notodonta dromedarius	0.4681	Positive
Xanthorhoe montanata	0.4624	Positive
Watsonalla binaria	0.4535	Positive
Noctua fimbriata	0.4396	Positive
Paradarisa consonaria	-0.5504	Negative
Amata phegea	-0.4856	Negative
Eupithecia exiguata	-0.4472	Negative
Arctia villica	-0.4339	Negative
Phytometra viridaria	-0.4339	Negative

Figure S4 Results of RDAs of species composition considering the gross effect of mowig on all



species of moths.

Table S20 Results of RDAs of species composition considering the gross effect of grazing on all species of moths. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S5).

Grazing		
Moths all species	***Regr. Coef.***	***Effect***
Trichopteryx polycommata	0.5725	Positive
Catephia alchymista	0.5156	Positive
Mormo maura	0.5156	Positive
Mesogona acetosellae	0.5156	Positive
Epirrhoe galiata	0.4569	Positive
Agrochola nitida	0.4519	Positive
Mythimna ferrago	-0.6056	Negative
Scotopteryx chenopodiata	-0.5966	Negative
Deltote deceptoria	-0.5529	Negative
Watsonalla cultraria	-0.5124	Negative
Acronicta psi	-0.4933	Negative
Clostera pigra	-0.4914	Negative
Chiasmia clathrata	-0.4704	Negative
Atypha pulmonaris	-0.4665	Negative
Drymonia dodonaea	-0.4638	Negative
Euthrix potatoria	-0.4629	Negative
Catarhoe cuculata	-0.4605	Negative
Mythimna conigera	-0.4597	Negative
Eulithis pyraliata	-0.4528	Negative
Polypogon tentacularius	-0.4523	Negative

Figure S5 Results of RDAs of species composition considering the gross effect of grazing on all species of moths.

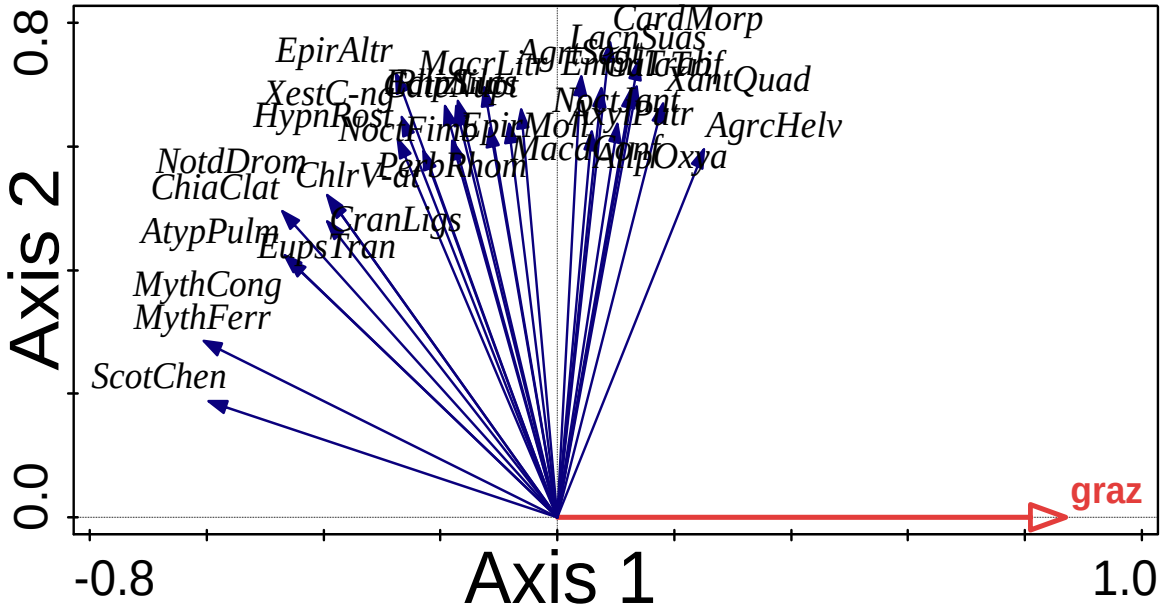


Table S21 Results of RDAs of species composition considering the gross effect of mowing on the subset of open-country species of plants. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S6).

Mowing		
Plant open-country species	***Regr. Coef.***	***Effect***
Viola canina	0.6296	Positive
Rhinanthus minor	0.5322	Positive
Bromus erectus	0.4866	Positive
Primula veris	0.4786	Positive
Carex montana	0.4520	Positive
Traunsteinera globosa	0.4463	Positive
Molinia arundinacea	0.4453	Positive
Trifolium montanum	0.4286	Positive
Sanguisorba officinalis	0.4241	Positive
Tragopogon orientalis	0.4179	Positive
Silene nutans	0.4151	Positive
Carex caryophyllea	0.4069	Positive
Knautia arvensis agg.	0.4031	Positive
Hypochaeris maculata	0.4024	Positive
Calamagrostis epigejos	-0.6355	Negative
Hypochaeris radicata	-0.4844	Negative
Achillea millefolium agg.	-0.4698	Negative
Carlina vulgaris agg.	-0.4252	Negative
Tanacetum vulgare	-0.4071	Negative
Verbascum sp.	-0.3980	Negative

Figure S6 Results of RDAs of species composition considering the gross effect of mowing on the subset of open-country species of plants.

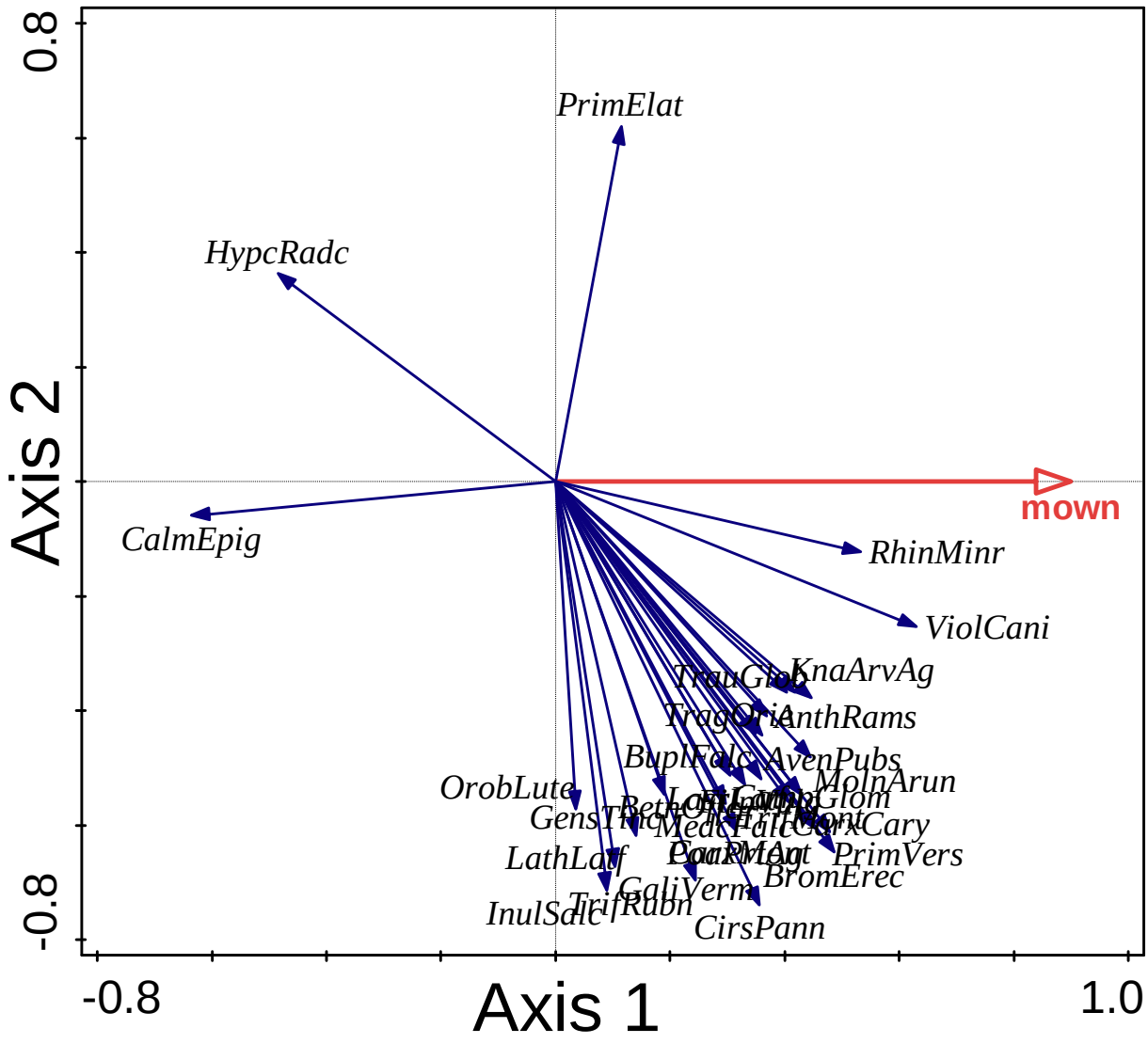


Table S22 Results of RDAs of species composition considering the gross effect of grazing on the subset of open-country species of plants. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S7).

Grazing		
Plant open-country species	***Regr. Coef.***	***Effect***
Carduus acanthoides	0.5924	Positive
Thlaspi perfoliatum	0.5870	Positive
Sisymbrium officinale	0.5600	Positive
Geranium columbinum	0.5541	Positive
Malva neglecta	0.5312	Positive
Odontites vernus	0.5312	Positive
Persicaria mitis	0.5312	Positive
Lapsana communis	0.5018	Positive
Arabidopsis thaliana	0.4923	Positive
Selinum carvifolia	0.4667	Positive
Anagallis arvensis	0.4485	Positive
Pilosella officinarum	0.4465	Positive
Eryngium campestre	0.4164	Positive
Festuca rubra	0.4088	Positive
Achillea millefolium agg.	0.4037	Positive
Juncus effusus	0.3988	Positive
Scorzoneroides autumnalis	0.3918	Positive
Leucanthemum vulgare agg.	-0.4672	Negative
Viola canina	-0.4380	Negative
Valeriana officinalis agg.	-0.4020	Negative

Figure S7 Results of RDAs of species composition considering the gross effect of grazing on the subset of open-country species of plants.

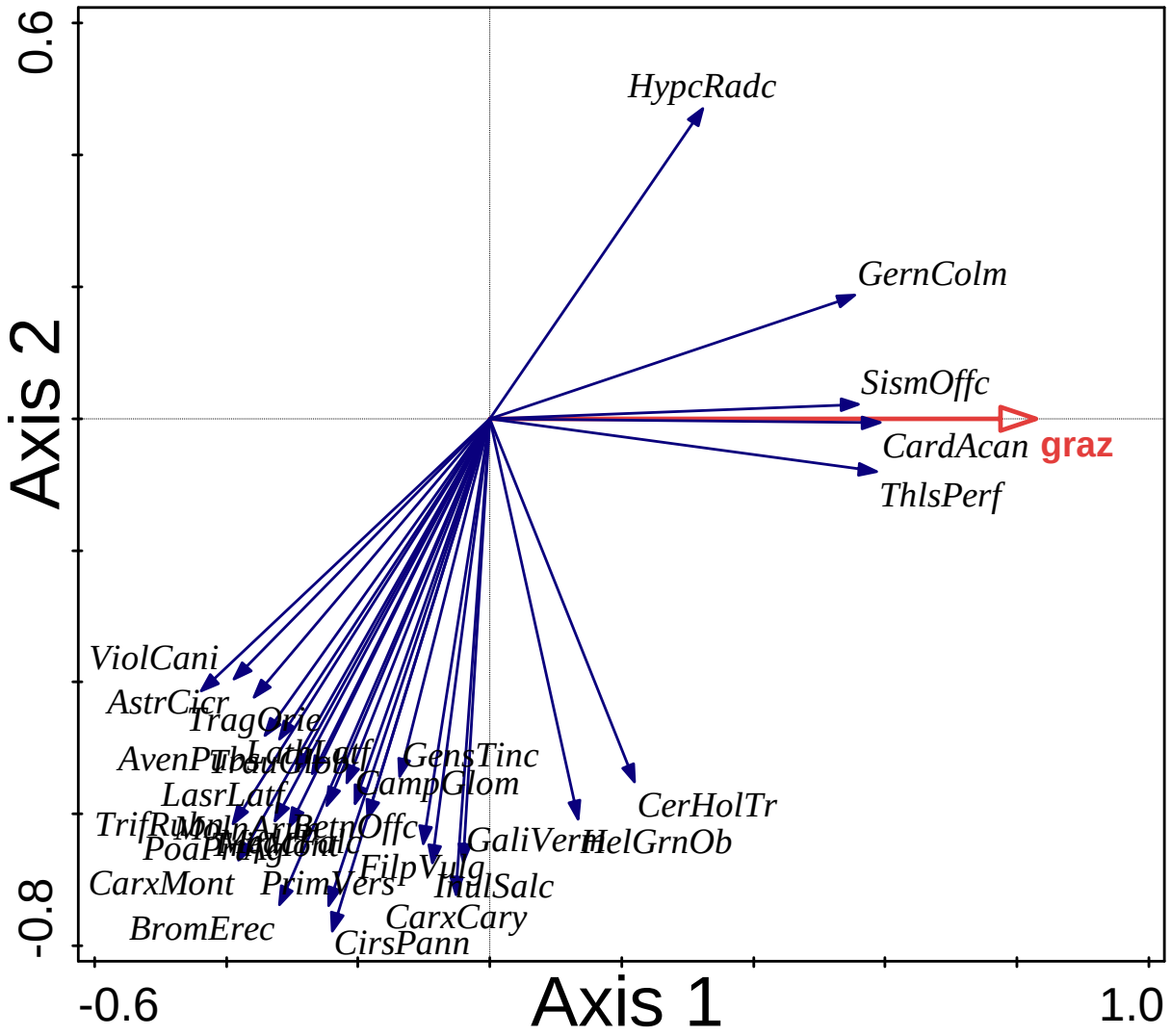
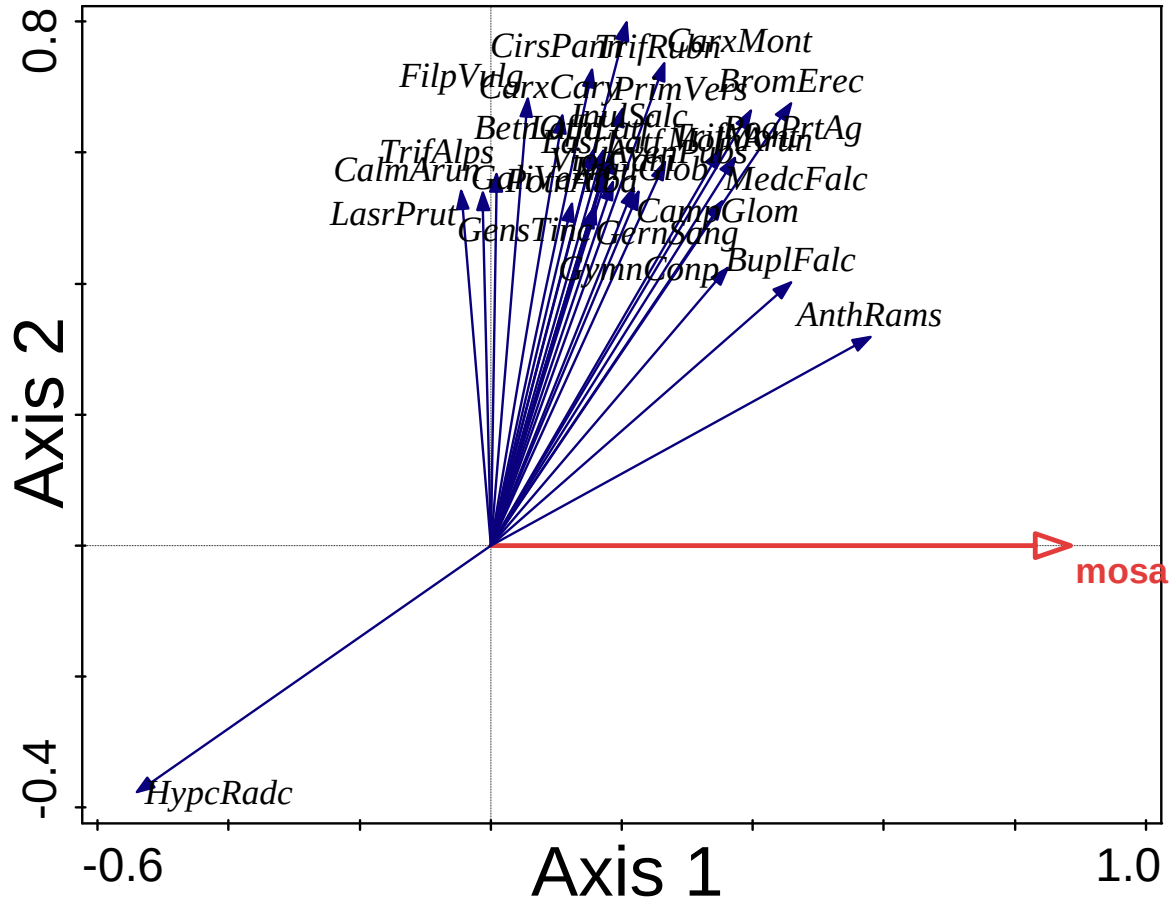


Table S23 Results of RDAs of species composition considering the gross effect of the mixed management on the subset of open-country species of plants. Only the first 20 species with the greatest explained variation for a statistically significant management type are listed in the tables (together with the corresponding regression coefficients and the effect of the management type) and shown in the ordination plots (Figure S8).

Mixed management		
Plant open-country species	***Regr. Coef.***	***Effect***
Anthericum ramosum	0.5794	Positive
Asperula cynanchica	0.4914	Positive
Polygonum aviculare agg.	0.4808	Positive
Bromus erectus	0.4583	Positive
Bupleurum falcatum	0.4581	Positive
Bromus inermis	0.4406	Positive
Veronica teucrium	0.4303	Positive
Sinapis arvensis	0.4181	Positive
Heracleum sphondylium	0.4101	Positive
Anthyllis vulneraria	0.3994	Positive
Seseli annuum	0.3974	Positive
Primula veris	0.3970	Positive
Inula ensifolia	0.3941	Positive
Erigeron acris agg.	0.3905	Positive
Arabis hirsuta	0.3864	Positive
Arctium sp.	0.3791	Positive
Atriplex patula	0.3756	Positive
Euphorbia helioscopia	0.3756	Positive
Hypochaeris radicata	-0.5407	Negative
Festuca rubra	-0.3981	Negative

Figure S8 Results of RDAs of species composition considering the gross effect of the mixed management on the subset of open-country species of plants.



Appendix B. Supplementary materials to Chapter 2.

Table S24 List of species. Marked with asterisk the focal species for dune habitat.

	Species
	Acacia cyanophylla Lindl.
	Achnatherum bromoides (L.) P. Beauv
	Aira caryophyllea L. subsp. *caryophyllea*
	Aira sp.
	Ajuga chamaepitys (L.) Schreb. subsp. *chamaepitys*
*	*Alkanna tinctoria* (L.) Tausch subsp. *tinctoria*
	Allium subhirsutum L.
	Ambrosia maritima L.
*	*Ammophila arenaria* (L.) Link subsp. *australis* (Mabille) Laínz
	Anagallis arvensis L. s.l.
	Anchusa azurea Mill.
	Anthemis arvensis L. s.l.
*	*Anthemis maritima* L.
	Anthoxanthum odoratum L. s.l
	Aphanes inexspectata Lippert
*	*Arbutus unedo* L.
	Arenaria serpyllifolia L. subsp. *serpyllifolia*
	Aristolochia rotunda L. s.l.
	Arrhenatherum elatius (L.) P. Beauv. ex J. & C. Presl s.l.
	Artemisia campestris L. subsp. *glutinosa* (J. Gay ex Besser) Batt.
	Arum italicum Mill. subsp. *italicum*
*	*Asparagus acutifolius* L.
	Asphodelus fistulosus L.
	Asterolinon linum-stellatum (L.) Duby
	Avena barbata Pott ex Link
	Avena fatua L.
	Ballota nigra L. s.l.
	Bellis annua L. subsp. *annua*
	Bellis perennis L.
	Berberis vulgaris L. s.l.
	Blackstonia perfoliata (L.) Huds. s.l.
	Bolboschoenus maritimus (L.) Palla
	Brachypodium rupestre (Host) Roem. & Schult.
*	*Brachypodium sylvaticum* (Huds.) P. Beauv. subsp. *sylvaticum*
	Brassica sp.
*	*Briza maxima* L.
	Briza media L.

Bromus commutatus Schrad.
Bromus diandrus Roth subsp. *diandrus*
Bromus hordeaceus L. s.l
Bromus madritensis L.
Bromus sterilis L.
Bupleurum baldense Turra
* *Cakile maritima* Scop. subsp. *maritima*
Calamagrostis epigejos (L.) Roth
Calendula arvensis L.
* *Calystegia soldanella* (L.) Roem. & Schult.
Carduus pycnocephalus L. subsp. *pycnocephalus*
Carex caryophyllea Latourr.
* *Carex distachya* Desf.
Carex divulsa Stokes
Carex flacca Schreb. s.l.
Carex halleriana Asso
Carex otrubae Podp.
Carex praecox Schreb.
Carex sp.
Carpobrotus acinaciformis (L.) L. Bolus
Catapodium balearicum (Willk.) H. Scholz
Catapodium rigidum (L.) C.E. Hubb. ex Dony s.l
Centaurium erythraea Rafn s.l.
Centranthus calcitrapae (L.) Dufr. subsp. *calcitrapae*
Cerastium glomeratum Thuill.
Cerastium pumilum Curtis
Cerastium semidecandrum L.
Cerastium sp.
Chamaedorea elegans Mart.
Chenopodium album L. s.l.
Chondrilla juncea L.
Cirsium creticum (Lam.) d'Urv. s.l.
* *Cistus creticus* L. subsp. *eriocephalus* (Viv.) Greuter & Burdet
* *Cistus salviifolius* L.
* *Clematis flammula* L.
Convolvulus arvensis L.
Convolvulus cantabrica L.
Coronilla scorpioides (L.) W.D.J. Koch
* *Corynephorus divaricatus* (Pourret) Breistr.
Crataegus monogyna Jacq.
Crepis leontodontoides All.
Crepis sp.
Crepis vesicaria L. s.l.

* *Cutandia maritima* (L.) Barbey
* *Cyclamen repandum* Sm. subsp. *repandum*
Cynosurus echinatus L.
* *Cyperus capitatus* Vand.
Dactylis glomerata L. s.l.
Danthonia decumbens (L.) DC. subsp. *decumbens*
* *Daphne gnidium* L.
Dasypyrum villosum (L.) P. Candargy, non Borbás
Daucus carota L. s.l.
Diplotaxis tenuifolia (L.) DC
Dittrichia viscosa (L.) Greuter s.l.
Dorycnium hirsutum (L.) Ser.
* *Echinophora spinosa* L.
Echium plantagineum L.
Elaeagnus × *ebbingei* Door.
* *Elymus farctus* (Viv.) Runemark ex Melderis subsp. *farctus*
Elymus repens (L.) Gould. subsp. *repens*
Emerus majus Mill. subsp. *majus*
Erianthus ravennae (L.) P.Beauv.
* *Erica arborea* L.
* *Erica multiflora* L.
* *Erica scoparia* L. subsp. *scoparia*
Erigeron canadensis L.
Erodium laciniatum (Cav.) Willd. subsp. *laciniatum*
* *Eryngium maritimum* L.
Eucalyptus globulus Labill.
Euonymus europaeus L.
* *Euphorbia exigua* L. subsp. *exigua*
Euphorbia peplus L.
Euphorbia terracina L.
Festuca arundinacea Schreb. s.l.
Filago pyramidata L.
Fumaria capreolata L. subsp. *capreolata*
Galium aparine L.
Galium spurium L.
Gastridium ventricosum (Gouan) Schinz & Thell.
Geranium columbinum L.
Geranium molle L.
Geranium purpureum Vill.
Geranium robertianum L.
Geranium rotundifolium L.
Geranium sp.
* *Halimium halimifolium* (L.) Willk. subsp. *halimifolium*

* *Hedera helix* L. s.l.
Hedypnois cretica (L.) Dum.Cours.
* *Helichrysum stoechas* (L.) Moench
Helminthotheca echioides (L.) Holub
Hieracium sp.
Hippocrepis biflora Spreng.
Hypericum perforatum L.
* *Hypochaeris achyrophorus* L.
* *Hypochaeris glabra* L.
Hypochaeris radicata L.
* *Juniperus oxycedrus* L. subsp. *macrocarpa* (Sibth. & Sm.) Neilr
* *Juniperus phoenicea* L. s.l.
* *Lagurus ovatus* L. s.l.
Lapsana communis L. subsp. *communis*
Lathyrus aphaca L. subsp. *aphaca*
Lathyrus sp.
Ligustrum vulgare L.
Linaria purpurea (L.) Mill.
Linaria vulgaris Mill. subsp. *vulgaris*
Linum bienne Mill.
* *Linum strictum* L. s.l.
Lobularia maritima (L.) Desv. subsp. *maritima*
* *Lonicera implexa* Aiton subsp. *implexa*
Lonicera sp.
* *Lotus cytisoides* L. s.l.
Lotus hispidus DC.
Luzula campestris (L.) DC.
Malva sylvestris L. subsp. *sylvestris*
* *Matthiola sinuata* (L.) R. Br.
* *Medicago littoralis* Loisel.
* *Medicago marina* L.
Medicago minima (L.) L.
Medicago rigidula (L.) All.
Medicago sp.
Melica arrecta Kuntze
Mentha sp.
Mercurialis annua L.
Muscari comosum (L.) Mill.
Myosotis arvensis (L.) Hill subsp. *arvensis*
Myosotis sp.
* *Myrtus communis* L. s.l.
Olea europaea L.
* *Ononis diffusa* Ten.

Ononis reclinata L.
* *Ononis variegata* L.
* *Osyris alba* L.
Oxalis corniculata L.
Oxalis sp.
Oxalis stricta L.
* *Pancratium maritimum* L.
Parapholis incurva (L.) C.E. Hubb.
Parietaria judaica L.
Paspalum distichum L.
* *Phillyrea angustifolia* L.
* *Phillyrea latifolia* L.
* *Phleum arenarium* L. subsp. *caesium* H. Scholz
Phragmites australis (Cav.) Trin. ex Steud. s.l.
Picris hieracioides L. s.l.
* *Pinus halepensis* Mill.
* *Pinus pinaster* Aiton s.l.
* *Pinus pinea* L.
Piptatherum miliaceum (L.) Coss. s.l.
* *Pistacia lentiscus* L.
* *Plantago bellardii* All.
Plantago crassifolia Forssk.
Plantago lanceolata L.
Plantago macrorrhiza Poir.
* *Polycarpon tetraphyllum* (L.) L. subsp. *diphyllum* (Cav.) O. Bolòs & Font Quer
Polypogon monspeliensis (L.) Desf.
* *Prasium majus* L.
Prunus spinosa L. subsp. *spinosa*
* *Pseudorlaya pumila* (L.) Grande
Pteridium aquilinum (L.) Kuhn subsp. *aquilinum*
* *Quercus cerris* L.
* *Quercus ilex* L. subsp. *ilex*
* *Quercus pubescens* Willd. subsp. *pubescens*
Ranunculus sardous Crantz s.l.
Raphanus raphanistrum L. s.l.
Reichardia picroides (L.) Roth.
* *Rhamnus alaternus* L. subsp. *alaternus*
Rosa sp.
* *Rosmarinus officinalis* L.
* *Rubia peregrina* L. s.l.
Rubus sp.
Rubus ulmifolius Schott

Rumex acetosella L. s.l.
* *Rumex bucephalophorus* L. s.l
* *Ruscus aculeatus* L.
* *Salsola kali* L.
Salvia sp.
Salvia verbenaca L.
Schoenus nigricans L.
Scrophularia auriculata L. subsp. *auriculata*
Sherardia arvensis L.
Sideritis romana L. subsp. *romana*
* *Silene canescens* Ten.
Silene italica (L.) Pers. subsp. *italica*
Silene sp.
Silene vulgaris (Moench) Garcke s.l.
Sixalix atropurpurea (L.) Greuter & Burdet s.l.
* *Smilax aspera* L.
Solanum nigrum L.
* *Sonchus bulbosus* (L.) N. Kilian & Greuter subsp. *bulbosus*
Sonchus oleraceus L.
Sonchus tenerrimus L.
Spartium junceum L.
* *Sporobolus virginicus* Kunth
Stachys officinalis (L.) Trevis.
Stachys sp.
Stellaria media (L.) Vill. s.l.
* *Tamus communis* L.
Taraxacum officinale (group)
Teucrium chamaedrys L. subsp. *chamaedrys*
Teucrium flavum L. s.l.
Torilis leptophylla (L.) Rchb. f.
Torilis sp.
* *Trachynia distachya* (L.) Link
Trifolium campestre Schreb.
Trifolium lappaceum L.
Trifolium repens L. s.l.
* *Trifolium scabrum* L. subsp. *scabrum*
Trifolium sp.
Triticum ovatum (L.) Raspail
Triticum triunciale (L.) Raspail
Ulmus minor Mill. s.l.
Urospermum dalechampii (L.) F.W. Schmidt
Urospermum picroides (L.) Scop. ex F.W. Schmidt
Verbascum blattaria L.

	Verbascum lychnitis L.
	Verbascum niveum Ten. subsp. *garganicum* (Ten.) Murb.
	Verbascum sp.
	Veronica agrestis L.
	Veronica arvensis L.
	Veronica sp.
*	*Viburnum tinus* L. subsp. *tinus*
	Vicia hirsuta (L.) Gray
	Vicia lathyroides L.
	Vicia lutea L.
	Vicia pseudocracca Bertol.
	Vicia sp.
	Vinca major L. subsp. *major*
*	*Viola alba* Besser subsp. *dehnhardtii* (Ten.) W. Becker
	Viola sp.
	Vulpia ciliata Dumort.
*	*Vulpia fasciculata* (Forssk.) Fritsch
	Vulpia ligustica (All.) Link

Table S25 Results of GAMs with binomial distribution carried out on species with more than 10 occurrences in the dataset based on CCA with distance from the coastline. Non-significant models are not shown.

GAM	Binomial			
Species	df	R^2(%)	F	P
Asparagus acutifolius	2	3.9	4.2	0.01615
Brachypodium rupestre	2	22.1	7.3	0.00027
Brachypodium sylvaticum ssp. *sylvaticum*	2	17.4	6.5	0.00088
Carex flacca	2	22.0	7.2	0.00039
Clematis flammula	2	9.3	4.0	0.02236
Euphorbia peplus	2	12.3	3.8	0.01784
Lotus cytisoides	2	22.8	2.1	0.01261
Phillyrea angustifolia	2	5.2	4.9	0.00914
Piptatherum miliaceum	2	7.0	3.7	0.02844
Quercus ilex ssp. *ilex*	2	4.4	3.5	0.02989
Rhamnus alaternus ssp. *alaternus*	2	7.6	6.1	0.00308
Silene vulgaris	2	7.5	3.7	0.02727
Sixalix atropurpurea	2	10.9	7.3	0.00169
Smilax aspera	2	3.5	3.8	0.02573

Table S26 Results of GAMs with binomial distribution carried out on species with more than 10 occurrences in the dataset, based on CCA with canopy cover. Non-significant models are not shown.

GAM	Binomial			
Species	df	R^2(%)	F	P
Pinus pinea				
Brachypodium rupestre	2	10.8	3.9	0.02379
Brachypodium sylvaticum ssp. *sylvaticum*	2	8.6	3.4	0.03928
Quercus ilex ssp. *ilex*	2	6.1	3.5	0.03448
Sixalix atropurpurea	2	33.1	3.3	0.04284
Pinus halepensis				
Lotus cytisoides	2	29.3	12.0	0.00004
Piptatherum miliaceum	2	13.0	3.4	0.03982
Sixalix atropurpurea	2	22.4	8.1	0.00082
Sporobolus virginicus	2	18.8	6.7	0.00231

Appendix C. Supplementary materials to Chapter 3.

Table S27 List of the recorded vascular plants.

	Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Total cover (%)	65	75	98	70	38	65	65	87	90	50	100	95	98	95	100	90	92	60	95	100
	Tree cover (%)	45	65	95	40	35	35	15	85	40	45	15	15	35	65	90	40	80	60	95	98
	Shrub cover (%)	25	15	50	45	0	35	55	0	10	8	100	2	90	35	80	70	35	0	0	8
	Herbaceous cover (%)	18	15	3	6	5	25	18	7	75	5	1	85	1	20	1	2	2	3	1	1
Amm are	*Ammophila arenaria* (L.) Link subsp. *australis* (Mabille) Laínz	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ana arv	*Anagallis arvensis* L.	2	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0
Ana foe	*Anagallis foemina* Mill.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aph arv	*Aphanes arvensis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Are ser	*Arenaria serpyllifolia* L.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Asp acu	*Asparagus acutifolius* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atr pro	*Atriplex prostrata* Boucher ex DC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bit bit	*Bituminaria bituminosa* (L.) C.H. Stirt.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bra ret	*Brachypodium retusum* (Pers.) P. Beauv.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bra rup	*Brachypodium rupestre* (Host) Roem. & Schult.	0	13	0	0	0	7	0	0	65	0	0	20	0	0	0	0	0	0	0	0
Cal sep	*Calystegia sepium* (L.) R. Br.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cap bur	*Capsella bursa-pastoris* (L.) Medik.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Car hir	*Cardamine hirsuta* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Car dis	*Carex distachya* Desf.	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	2	1	0
Car div	*Carex divulsa* Stokes	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Cat rig	*Catapodium rigidum* (L.) C.E. Hubb. ex Dony	0	0	0	0	0	2	2	0	0	1	0	0	0	6	0	0	0	0	0	0
Cer glo	*Cerastium glomeratum* Thuill.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cre sp.	*Crepis* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyc rep	*Cyclamen repandum* Sm.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dit vis	*Dittrichia viscosa* (L.) Greuter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dor hir	*Dorycnium hirsutum* (L.) Ser.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eup hel	*Euphorbia helioscopia* L.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fes aru	*Festuca arundinacea* Schreb.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Fra ang	*Fraxinus angustifolia* Vahl subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gal mur	*Galium murale* (L.) All.	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas ven	*Gastridium ventricosum* (Gouan) Schinz & Thell.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ger col	*Geranium columbinum* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ger mol	*Geranium molle* L.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ger rob	*Geranium robertianum* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hed hel	*Hedera helix* L.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hel ech	*Helminthotheca echioides* (L.) Holub	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hie sp.	*Hieracium* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyp per	*Hypericum perforatum* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyp ach	*Hypochaeris achyrophorus* L.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inu con	*Inula conyzae* (Griess.) Meikle	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0
Iso his	*Isoëtes histrix* Bory	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iso cer	*Isolepis cernua* (Vahl) Roem. & Schult.	0	0	0	2	2	0	0	3	0	0	0	0	0	0	0	1	1	0	0	0

Jun acu	*Juncus acutus* L.	0	0	0	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0	0
Jun buf	*Juncus bufonius* L.	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
Jun mar	*Juncus maritimus* Lam.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun sor	*Juncus sorrentinii* Parl.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun oxy	*Juniperus oxycedrus* L. subsp. *macrocarpa* (Sibth. & Sm.) Neilr.	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Lat inc	*Lathyrus incospicuus* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lau nob	*Laurus nobilis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lot cor	*Lotus corniculatus* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lot his	*Lotus hispidus* DC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyt hys	*Lythrum hyssopifolia* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Med mar	*Medicago marina* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Med min	*Medicago minima* (L.) L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Men arv	*Mentha arvensis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myr com	*Myrtus communis* L.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxa cor	*Oxalis corniculata* L.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pan mar	*Pancratium maritimum* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Par sp.	*Parietaria* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phy ang	*Phillyrea angustifolia* L.	5	5	10	45	0	15	10	0	8	0	0	0	25	0	0	0	0	0	0	0
Phl are	*Phleum arenarium* L. subsp. *caesium* H. Scholz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phr aus	*Phragmites australis* (Cav.) Trin. ex Steud.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pic hie	*Picris hieracioides* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pin pin	*Pinus pinea* L.	45	65	95	40	30	35	15	85	30	45	15	15	35	65	90	40	65	60	95	98
Pip mil	*Piptatherum miliaceum* (L.) Coss.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pis len	*Pistacia lentiscus* L.	10	10	40	1	0	20	45	0	5	5	100	2	70	15	80	70	35	0	0	8
Pla cor	*Plantago coronopus* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa ann	*Poa annua* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa tri	*Poa trivialis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pol tet	*Polycarpon tetraphyllum* (L.) L. subsp. *diphyllum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	(Cav.) O. Bolòs & Font Quer																				
Pol mon	*Polypogon monspeliensis* (L.) Desf.	0	0	0	0	0	0	0	0	0	0	0	65	0	0	0	0	0	0	0	0
Pol sub	*Polypogon subspathaceus* Req.	0	0	0	2	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Pul dys	*Pulicaria dysenterica* (L.) Bernh.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Que ile	*Quercus ilex* L.	0	0	0	0	0	0	0	0	10	0	0	0	0	0	3	0	15	0	0	0
Que sub	*Quercus suber* L.	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0
Rha ste	*Rhagadiolus stellatus* (L.) Gaertn.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rob pse	*Robinia pseudacacia* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ros sp.	*Rosa* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ros off	*Rosmarinus officinalis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
Rub per	*Rubia peregrina* L.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rub hir	*Rubus hirtus* Waldst. & Kit.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rub sp.	*Rubus* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sag ape	*Sagina apetala* Ard.	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sam val	*Samolus valerandi* L.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Sar fru	*Sarcocornia fruticosa* (L.) A.J. Scott	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sid rom	*Sideritis romana* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smi asp	*Smilax aspera* L.	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0
Son asp	*Sonchus asper* (L.) Hill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Son bul	*Sonchus bulbosus* (L.) N. Kilian & Greuter	0	1	0	0	0	2	0	0	5	0	0	0	0	0	0	0	0	1	0	0
Son sp.	*Sonchus* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ste med	*Stellaria media* (L.) Vill.	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Tam com	*Tamus communis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tra dis	*Trachynia distachya* (L.) Link	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0
Ulm min	*Ulmus minor* Mill.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Urt dio	*Urtica dioica* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ver arv	*Veronica arvensis* L.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vic sat	*Vicia sativa* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vul cil	*Vulpia ciliata* Dumort.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vul fas	*Vulpia fasciculata* (Forssk.) Fritsch	2	0	0	0	0	0	1	0	0	2	0	0	0	10	0	0	0	0	0	0
Xan ori	*Xanthium orientale* L. subsp. *italicum* (Moretti) Greuter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table S28 List of the recorded mite species.

		Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Aph aca	*Aphelacarus acarinus* (Berlese, 1910)		0	0	0	0	0	0	0	0	0	17	0	0	0	5	0	0	0	0	0	0
Cos plu	*Cosmochthonius plumatus* Berlese, 1910		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cos pon	*Cosmochthonius ponticus* Gordeeva, 1980		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phy emm	*Phyllozetes emmae* (Berlese, 1910)		0	0	2	0	0	0	0	0	0	2	7	0	0	19	7	0	0	0	0	1
Hap san	*Haplochthonius sanctaluciae* Bernini 1973		0	0	0	0	0	0	0	0	0	2	0	0	0	11	0	0	0	0	0	0
Hap sim	*Haplochthonius simplex* Willmann 1930		0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Sph spl	*Sphaerochthonius splendidus* (Berlese, 1904)		10	19	40	0	0	3	0	0	24	0	47	3	97	0	48	30	9	1	0	76
Bur tyr	*Bursoplophora tyrrhenica* Bernini, 1973		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Bra bim	*Brachychthonius bimaculatus* Willmann, 1936		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Bra hir	*Brachychthonius hirtus* Moritz, 1976		0	0	0	0	0	0	0	0	0	2	0	0	1	7	0	0	0	0	0	5
Bra imp	*Brachychthonius impressus* Moritz, 1976		0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lio bre	*Liochthonius brevis* (Michael, 1888)		1	1	15	0	0	0	2	0	18	0	0	75	0	0	2	0	2	1	0	37
Lio str	*Liochthonius strenzkei* Forsslund, 1963		2	0	0	0	0	0	0	0	0	0	1	28	1	0	0	0	0	0	0	0

Poe ita	*Poecilochthonius italicus* (Berlese, 1910)	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sel cri	*Sellnickochthonius cricoides* (Wies-Fog, 1948)	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sel imm	*Sellnickochthonius immaculatus* (Forsslund, 1942)	3	0	0	0	0	0	0	0	1	0	29	0	2	0	3	0	0	0	0	3
Sel mer	*Sellnickochthonius meridionalis* (Bernini, 1973)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sel ros	*Sellnickochthonius rostratus* (Jacot, 1936)	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Sel sue	*Sellnickochthonius suecicus* (Forsslund, 1942)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Pht glo	*Phthiracarus globosus* (C.L. Koch, 1841)	2	0	0	0	0	1	4	0	0	0	1	0	7	3	0	1	3	0	1	5
Pht ita	*Phthiracarus italicus* (Oudemans, 1900)	0	0	0	0	0	0	0	1	0	0	0	8	0	0	0	1	1	0	0	4
Pht lae	*Phthiracarus laevigatus* (C.L. Koch, 1844)	0	1	0	0	0	0	0	0	0	0	7	0	0	0	1	0	0	0	0	0
Atr phy	*Atropacarus (Atropacarus) phyllophorus* (Berlese, 1904)	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Ste car	*Steganacarus (Steganacarus) carusoi* Bernini & Avanzati, 1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Ste bre	*Steganacarus* (*Tropacarus*) *brevipilus* (Berlese, 1923)	7	4	3	1	0	0	2	0	11	0	3	4	2	1	12	8	3	0	0	13
Ori ber	*Oribotritia berlesei* (Michael, 1898)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	0	0	0	0	0
Mic mini	*Microtritia minima* (Berlese, 1904)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Rhy ard	*Rhysotritia ardua* (C.L. Koch, 1841)	1	0	6	10	0	7	0	0	2	1	12	2	5	0	20	0	1	0	0	25
Epi cyl	*Epilohmannia cylindrica* (Berlese, 1910)	1	0	6	1	3	0	0	0	0	0	1	3	1	1	2	8	0	0	1	6
Cam spi	*Camisia spinifer* (C.L. Koch, 1835)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Art med	*Arthrodamaeus mediterraneus* Subias L.S., Arillo & Subias J., 1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
Lic pul	*Licnodamaeus pulcherrimus* (Paoli, 1908)	0	0	0	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0
																					195

Lic lat	*Licnobelba latiflabellata* (Paoli, 1908)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Met par	*Metabelba (Metabelba) parapulverosa* Moritz, 1966	0	0	0	0	0	4	0	0	3	0	0	0	0	0	9	0	2	0	0	0
Met int	*Metabelbella interlamellaris* Pérez-Iñigo, 1987	0	2	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5
Cep peg	*Cepheus pegazzonae* Bernini & Nannelli, 1982	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dam asp	*Damaeolus asperatus* (Berlese, 1904)	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1
Fos lac	*Fosseremus laciniatus* (Berlese, 1905)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Eur val	*Euremaeus valkanovi* (Kunst, 1957)	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	1
Mic eme	*Microzetorchestes emeryi* (Coggi, 1898)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Zet gra	*Zetorchestes grandjeani* Krisper, 1987)	0	4	4	0	0	3	0	0	0	0	0	0	5	0	0	0	0	0	0	1
Lia cor	*Liacarus coracinus* (C.L. Koch, 1841)	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0
Lia xyl	*Liacarus xylariae* (Schrank, 1803)	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Xen cly	*Xenillus clypeator* Robineau-Desvoidy, 1839	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0
Xen teg	*Xenillus tegeocranus* (Hermann, 1804)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cer qua	*Ceratoppia quadridentata* (Haller, 1882)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Car qua	*Carabodes quadrangulus* Bernini, 1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Tec ala	*Tectocepheus alatus* Berlese, 1913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Tec sar	*Tectocepheus sarekensis* Trägårdh, 1910	15	5	0	41	0	25	20	0	0	0	49	22	57	20	25	0	3	1	0	2
Tec vel	*Tectocepheus velatus* (Michael, 1880)	0	1	1	0	0	4	0	0	0	0	4	1	1	0	4	0	2	1	0	18
Mac dra	*Machuella draconis* Hammer, 1961	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ber bic	*Berniniella* (*Berniniella*) *bicarinata* (Paoli, 1908)	2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0
Ber hyp	*Berniniella* (*Hypogeoppia*) *hypogea* (Paoli, 1908)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ber n.s	*Berniniella* n.sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Cor kos	*Corynoppia kosarovi* (Jeleva, 1962)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Dis orn	*Dissorhina ornata* (Oudemans, 1900)	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Gra para	*Graptoppia* (*Graptoppia*) *paraanalis* Subias & Rodriguez, 1985	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
Gra parv	*Graptoppia* (*Graptoppia*) *parva* (Kok, 1967)	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gra sp.	*Graptoppia* (*Graptoppia*) sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Mic minu	*Microppia minus* (Paoli, 1908)	4	3	23	0	4	9	9	6	28	20	17	6	5	4	6	1	0	0	6	26
Opp den	*Oppia denticulata* (G. & R. Canestrini, 1882)	0	0	11	0	0	11	1	1	2	0	0	3	0	1	0	1	1	0	0	3
Opp nov	*Oppiella* (*Oppiella*) *nova* (Oudemans, 1902)	0	0	0	0	8	0	0	0	1	0	0	1	0	0	0	19	0	0	0	1
Opp sim	*Oppiella* (*Rhinoppia*) *similifallax* Subias & Minguez, 1986	6	0	0	0	0	0	166	0	0	0	0	0	0	0	1	0	1	1	0	0
Opp sub	*Oppiella* (*Rhinoppia*) *subpectinata* (Oudemans, 1900)	0	0	140	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	69
Oxy dec	*Oxyoppioides decipiens* (Paoli, 1908)	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ram ins	*Ramusella* (*Inscultoppia*) *insculpta* (Paoli, 1908)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0
Ram str	*Ramusella* (*Rectoppia*) *strinatii* (Mahunka, 1980)	17	1	2	1	0	1	1	0	1	0	2	4	0	0	0	5	16	0	0	38
Suc tri	*Suctobelba trigona* (Michael, 1888)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Suc acu	*Suctobelbella acutidens (*Forsslund, 1941)	0	2	14	0	0	0	0	0	0	0	0	5	0	0	0	1	1	0	0	4
Suc for	*Suctobelbella forsslundi* (Strenzke, 1950)	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Suc sar	*Suctobelbella sarekensis* (Forsslund, 1941)	0	0	25	0	0	0	0	0	7	0	0	12	0	0	0	0	0	0	0	2
Suc sub	*Suctobelbella subcornigera* (Forsslund, 1941)	7	2	80	0	0	4	7	0	29	0	1	2	0	0	2	2	18	0	0	8
Sca cor	*Scapheremaeus corniger* (Berlese, 1908)	0	1	1	0	0	1	0	0	1	1	0	0	2	0	1	0	0	1	0	2
Mic bre	*Micreremus brevipes* (Michael, 1888)	0	0	0	0	0	0	0	0	1	0	0	0	3	0	1	0	0	0	0	0

Lic giu	*Licneremaeus giustii* Bernini, 1973	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Lic lic	*Licneremaeus licnophorus* (Michael, 1882)	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lie lon	*Liebstadia longior* (Berlese, 1908)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ori tib	*Oribatula tibialis* (Nicolet, 1855)	0	0	0	0	0	0	0	9	1	0	0	34	0	1	0	3	2	2	1	14
Pha luc	*Phauloppia lucorum* (C.L. Koch, 1841)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Zyg gla	*Zygoribatula glabra* (Michael, 1890)	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	41	0	0	0	0
Zyg pro	*Zygoribatula propinqua* (Oudemans, 1900)	41	2	9	1	0	2	4	0	0	0	9	0	28	0	3	0	11	1	2	5
Hap	Haplozetidae	0	0	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sch ini	*Scheloribates* (*Hemileius*) *initialis* (Berlese, 1908)	7	11	6	5	0	5	4	0	0	0	27	0	18	6	30	2	13	0	0	10
Sch lae	*Scheloribates*(*Scheloribates*) *laevigatus* (C.L. Koch, 1835)	0	0	0	0	1	0	0	0	232	1	0	31	0	4	0	0	0	0	0	0
Cha pus	*Chamobates pusillus* (Berlese, 1895)	0	69	6	12	0	46	2	1	16	0	0	3	0	4	1	8	3	4	2	18
Cer lat	*Ceratozetes laticuspidatus* Menke, 1964	0	12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pun pun	*Punctoribates punctum* (C.L. Koch, 1839)	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hum ros	*Humerobates rostrolamellatus* Grandjean, 1936	1	1	0	0	0	2	0	0	1	0	1	0	3	1	5	1	2	0	3	1
Eup acr	*Eupelops acromios* (Hermann, 1804)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eup gem	*Eupelops geminus* (Berlese, 1916)	0	5	0	0	0	0	0	0	54	0	0	0	0	0	1	0	0	0	0	0
Eup tor	*Eupelops torulosus* (C.L. Koch, 1839)	0	4	3	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Pel gib	*Peloptulus gibbus* Mihelčič, 1957	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ori bre	*Oribatella brevipila* Bernini, 1977	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ach col	*Achipteria coleoptrata* (Linnaeus, 1758)	0	0	0	0	0	0	0	0	6	0	0	3	1	0	0	0	0	0	0	0
Ach nit	*Achipteria nitens* (Nicolet, 1855)	20	12	0	0	0	0	0	0	49	0	0	0	1	0	28	29	0	0	0	0
All ala	*Allogalumna alamellae* (jacot, 1935)	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0

Gal obv	*Galumna obvia* (Berlese, 1914)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Per myr	*Pergalumna myrmophila* (Berlese, 1914)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Per ner	*Pergalumna nervosa* (Berlese, 1914)	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	1	0
Pil cra	*Pilogalumna crassiclava* (Berlese, 1914)	0	0	0	1	0	0	11	0	0	0	1	0	0	0	1	1	0	0	0	0

Table S29 Physical and chemical properties measured in soil samples.

Plot	1	2	3	4	5	6	7	8	9	10
pH	6.83	4.99	6.31	5.80	5.96	5.95	6.46	5.77	7.25	7.16
NaCl (g/kg)	0.11930	0.52460	0.11800	0.15620	0.37490	0.10220	0.10620	0.22940	0.18920	0.15400
CaCO3 (g/kg)	50	70	60	50	160	100	110	70	32	170
SOM (g/kg)	101.51878	112.70696	56.92031	38.83304	59.74338	33.08329	56.05469	58.69391	215.46961	34.33560
TN (g/kg)	2.500	0.001	2.300	3.600	2.200	0.700	2.300	1.000	7.500	0.001
FC (g/kg)	352.12259	505.01470	315.70601	383.02645	335.13475	323.37268	388.92890	363.84322	703.93982	496.13112
D (Kg/L)	2.0000	1.6000	2.0555	1.8615	1.9970	2.0740	1.8960	1.9445	1.5385	2.0125

Plot	11	12	13	14	15	16	17	18	19	20
pH	7.86	5.72	5.12	7.57	7.71	5.54	6.20	6.34	4.36	7.34
NaCl (g/kg)	0.19200	4.33000	1.66700	0.17690	0.08990	0.21530	0.26030	0.48520	1.80900	0.08036
CaCO3 (g/kg)	220	70	220	290	230	35	75	50	100	150
SOM (g/kg)	17.83637	56.56971	26.10000	23.51798	13.61907	106.54917	72.97561	29.75600	74.02370	40.32741
TN (g/kg)	0.100	2.500	1.100	0.001	1.600	8.100	0.900	1.700	3.700	1.100
FC (g/kg)	250.67035	479.53792	339.11169	627.30193	274.73783	500.86342	481.44610	324.17228	440.48395	382.81792
D (Kg/L)	2.1065	1.7820	2.0625	1.8975	2.1550	1.9730	1.6975	1.9285	1.8035	2.0850

Appendix D. Supplementary materials to Chapter 4.

Table S30. List of the recorded species.

SPECIES
Ammophila arenaria (L.) Link subsp. *australis* (Mabille) Laínz
Ampelodesmos mauritanicus (Poir.) T. Durand & Schinz
Anacyclus radiatus Loisel. subsp. *radiatus*
Anagallis arvensis L. subsp. *arvensis*
Andryala integrifolia L.
Anthemis maritima L.
Arenaria leptoclados (Rchb.) Guss.
Aristolochia rotunda L. s.l.
Arundo donax L.
Asparagus acutifolius L.
Atriplex prostrata Boucher ex DC.
Avena barbata Pott ex Link
Brachypodium sylvaticum (Huds.) P. Beauv. subsp. *sylvaticum*
Briza maxima L.
Bromus rubens L.
Cakile maritima Scop. subsp. *maritima*
Calystegia sepium (L.) R. Br. subsp. *sepium*
Calystegia soldanella (L.) Roem. & Schult
Campanula rapunculus L.
Carex otrubae Podp.
Carpobrotus acinaciformis (L.) L. Bolus

Catapodium balearicum (Willk.) H. Scholz

Catapodium rigidum (L.) C.E. Hubb. ex Dony s.l

Centaurea sphaerocephala L.

Centaurium erythraea Rafn subsp. *erythraea*

Cerastium glomeratum Thuill.

Chamaesyce peplis (L.) Prokh.

Cirsium sp.

Cistus creticus L. subsp. *eriocephalus* (Viv.) Greuter & Burdet

Clematis flammula L.

Clematis vitalba L.

Clypeola jonthlaspi L. subsp. *jonthlaspi*

Crepis sp.

Crithmum maritimum L.

Crucianella maritima L.

Cutandia maritima (L.) Richter

Cyperus capitatus Vand.

Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman

Daphne gnidium L.

Daucus carota L. s.l.

Dorycnium hirsutum (L.) Ser.

Echinophora spinosa L.

Elymus athericus (Link) Kerguélen

Elymus farctus (Viv.) Runemark ex Melderis subsp. *farctus*

Equisetum ramosissimum Desf.

Erica multiflora L.

Erica scoparia L. subsp. *scoparia*

Erigeron canadensis L.

Eryngium maritimum L.

Euphorbia barrelieri Savi subsp. *barrelieri*

Euphorbia paralias L.

Euphorbia peplus L.

Euphorbia terracina L.

Festuca arundinacea Schreb. s.l

Fraxinus angustifolia Vahl subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso

Fumaria sp.

Galium aparine L.

Galium murale (L.) All.

Hedera helix L.

Helichrysum stoechas (L.) Moench

Helminthotheca echioides (L.) Holub

Hordeum marinum Huds. subsp. *marinum*

Hypochaeris radicata L.

Juncus acutus L. subsp. *acutus*

Juniperus oxycedrus L. subsp. *macrocarpa* (Sibth. & Sm.) Neilr.

Juniperus phoenicea L. subsp. *phoenicea*

Lagurus ovatus L.

Limbarda crithmoides (L.) Dumort. s.l.

Linum strictum L. s.l.

Lonicera implexa Aiton subsp. *implexa*

Malcolmia ramosissima (Desf.) Gennari

Matthiola sinuata (L.) R. Br.

Matthiola tricuspidata (L.) R. Br.

Medicago littoralis Loisel.

Medicago marina L.

Medicago minima (L.) L.

Myrtus communis L.

Odontites vernus (Bellardi) Dumort

Oenanthe peucedanifolia Pollich

Onobrychis caput-galli (L.) Lam.

Ononis variegata L.

Opuntia ficus-indica (L.) Mill.

Osyris alba L.

Otanthus maritimus (L.) Hoffmanns. & Link subsp. *maritimus*

Pancratium maritimum L.

Petroselinum crispum (Mill.) Fuss

Phillyrea angustifolia L.

Phleum arenarium L.

Phragmites australis (Cav.) Trin. ex Steud. s.l.

Picris hieracioides L. s.l.

Pinus halepensis Miller

Pinus pinaster Aiton

Pinus pinea L.

Pistacia lentiscus L.

Pittosporum tobira (Thunb.) W.T. Aiton

Prasium majus L.

Prunus spinosa L. subsp. *spinosa*

Pseudorlaya pumila (L.) Grande

Psilurus incurvus (Gouan) Schinz & Thell.

Quercus ilex L. subsp. *ilex*

Quercus pubescens Willd. subsp. *pubescens*

Raphanus raphanistrum L. subsp. *raphanistrum*

Reichardia picroides (L.) Roth.

Reseda lutea L. subsp. *lutea*

Rhamnus alaternus L. subsp. *alaternus*

Rosa sempervirens L.

Rosmarinus officinalis L.

Rubia peregrina L.

Rubus ulmifolius Schott

Rumex acetosella L. s.l.

Rumex crispus L.

Ruscus aculeatus L.

Salsola soda L.

Salsola tragus L. s.l.

Scabiosa columbaria L. s.l.

Scirpoides holoschoenus (L.) Soják

Seseli tortuosum L.

Silene badaroi Breistr.

Silene canescens Ten.

Silene latifolia Poir. subsp. *alba* (Mill.) Greuter & Burdet

Silene otites (L.) Wibel s.l.

Smilax aspera L.

Sonchus arvensis L. s.l.

Sonchus bulbosus (L.) N. Kilian & Greuter

Spartium junceum L.

Sporobolus virginicus Kunth

Stachys maritima Gouan

Tamarix africana Poir.

Trifolium angustifolium L. subsp. *angustifolium*

Trifolium campestre Schreb.

Triglochin bulbosum L. subsp. *barrelieri* (Loisel.) Rouy

Ulmus minor Mill. s.l.

Urospermum dalechampii (L.) F.W. Schmidt

Urospermum picroides (L.) Scop. ex F.W. Schmidt

Verbascum sinuatum L.

Vinca major L. subsp. *major*

Vulpia fasciculata (Forssk.) Fritsch

Xanthium orientale L. subsp. *italicum* (Moretti) Greuter

Xanthium spinosum L.