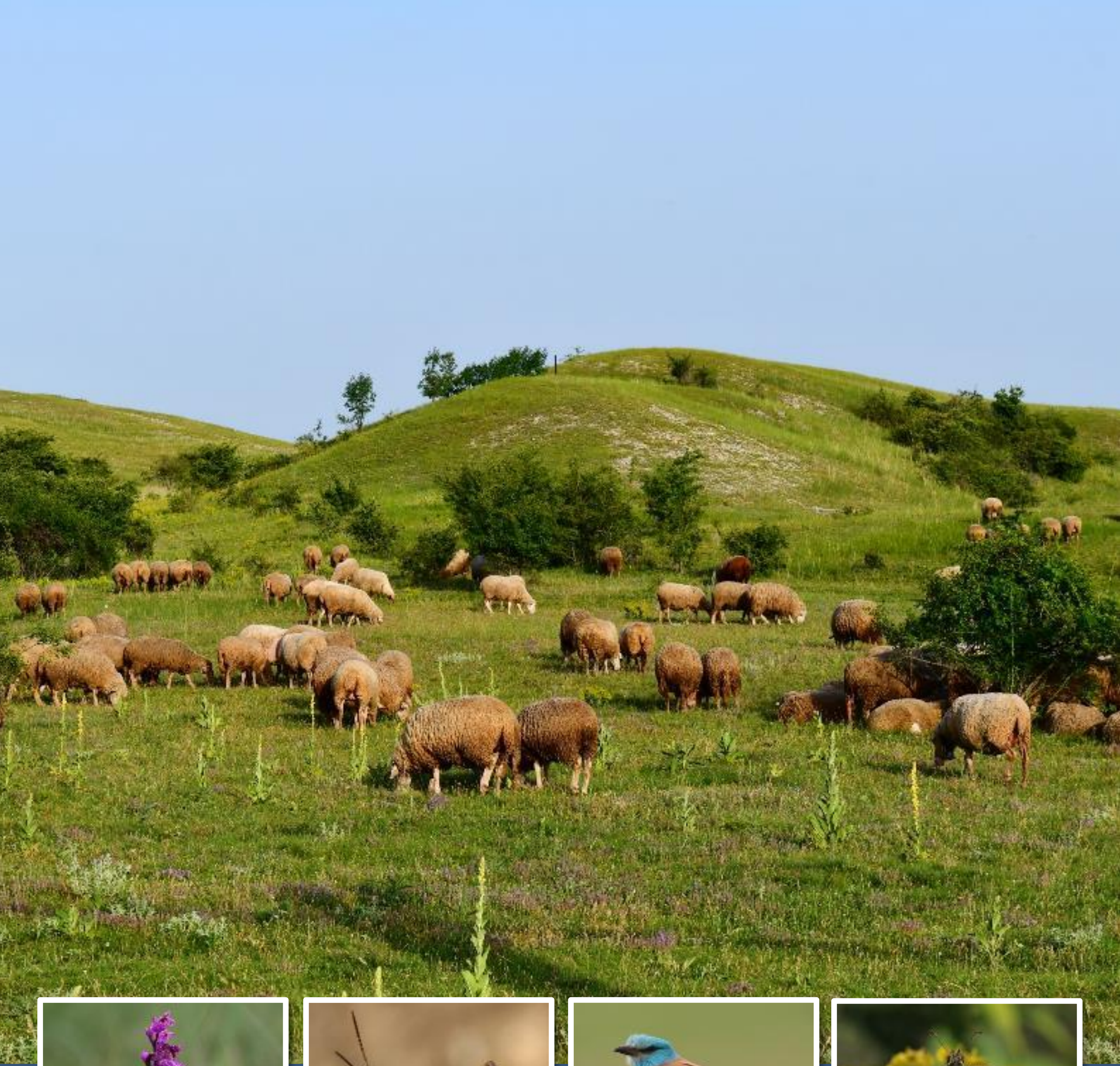



Biodiversity conservation in the cultural landscape of the Vértes Hills

Recommendations for habitat management in dry calcareous grasslands

Franz Löffler, Sándor Bérces, Jonas Brüggeshemke, Zoltán Kenyeres & Thomas Fartmann

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Summary

Land-use change is considered to be the main driver of biodiversity loss worldwide. While in much of Central and North-western Europe, semi-natural habitats have suffered a severe decline due to the large-scale intensification of agriculture under the EU's Common Agricultural Policy (CAP), the newer EU Member States of Central and Eastern Europe (CEE) are still characterised by a lower land-use intensity and a higher proportion of these valuable habitats on average. As they are of outstanding importance for biodiversity conservation, these habitats are often protected under the EU Habitats Directive.

Within the scope of the Advisory Assistance Programme (AAP) of the German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN), recommendations for habitat management in dry calcareous grasslands were developed as part of a collaborative project, using the example of the Natura 2000 site Vértes (HUDI 30001) in Hungary. Despite being protected under the EU Habitats Directive, these habitats in the project region are severely threatened by succession as a result of the abandonment of livestock grazing. Based on data on the biodiversity of four indicator groups sampled in 40 study plots, representative of dry calcareous grasslands, the following factors were found to be beneficial for high biodiversity in the dry calcareous grasslands:

(1) the presence of large-scale and well-connected habitat patches,
(2) a high habitat quality and heterogeneity within grassland patches and
(3) the maintenance of early and mid-successional stages within the grasslands.

According to these findings, a re-implementation of low-intensity land-use practices, such as livestock grazing, should be aimed for in future conservation measures. This document provides specific recommendations for habitat management that would be appropriate for preserving biodiversity in dry calcareous grasslands from a scientific point of view. At the same time, it highlights the challenges that the implementation of habitat management faces. A key challenge in the Vértes Hills is that most of the dry calcareous grasslands are subject to local forestry plans, which currently do not provide for grazing with livestock and make the utilisation of agri-environmental funding currently impossible. As this contradicts the objectives of the EU Habitats Directive in the long term, adjustments are needed to enable habitat management and secure the outstanding biodiversity in the Vértes Hills.

1 Background

1.1 Global biodiversity loss

Biodiversity is of great importance to our society as it provides a wide range of ecosystem services and thus is also of economic value. In the face of the dramatic scale of the global extinction of species (De Vos et al. 2014, Cardoso et al. 2020), the development of sustainable biodiversity conservation strategies in line with the 2030 Agenda for Sustainable Development is perhaps one of the greatest challenges facing our society (Rockström et al. 2009, Samways et al. 2020). With the multilateral Convention on Biological Diversity, more than 190 countries worldwide have committed themselves to counteracting this trend (CBD 1992).

Land-use change is considered to be the main driver of biodiversity loss worldwide (Foley et al. 2009, Cardoso et al. 2020). Since the mid-20th century, large parts of Europe have undergone a rapid transformation from traditionally used small-scale farmland to heavily industrialised agricultural landscapes. This process has led to far-reaching changes in the habitats of Europe's cultural landscapes. In addition to increasing urban sprawl, land-use change has especially caused a significant decrease in the area of low-intensity farmland (MacDonald et al. 2000, Robinson & Sutherland 2002, Fartmann 2017, Löffler et al. 2020). In particular, the latter is of outstanding value for the protection of biodiversity and is therefore considered to be High Nature Value farmland (HNV farmland) (Veen et al. 2009). As a result, in many regions of Europe, the occurrence of species dependent on HNV farmland is now limited to a few habitat fragments that are surrounded by an intensively used, hostile landscape matrix. Furthermore, the maintenance of species-rich communities in the remaining habitat fragments is often threatened by reduced habitat quality due to a lack of management, inappropriate or too intensive land use as well as high levels of atmospheric nitrogen deposition (Fischer & Lindenmayer 2007, Veen et al. 2009, Fartmann 2017, Fartmann et al. 2021). It is furthermore assumed that the impact of other drivers, such as climate change, will increase dramatically in the future, further exacerbating biodiversity loss in fragmented landscapes (Thomas et al. 2004, Fartmann 2017, Fartmann et al. 2021).

More than 40% of the terrestrial area of the EU-27 countries is used for agriculture (EEA 2024). European agricultural landscapes therefore play a key role in the conservation of biodiversity (Henle et al. 2008, Veen et al. 2009, Sutcliffe et al. 2015). Although Europe's agricultural area has only decreased slightly since the mid-20th century, farmland habitats exhibited the greatest declines in biodiversity over this period all over Europe (Donald et al. 2006, Dröschmeister et al. 2012, BMUB 2015, Fartmann et al. 2021). Different regional socio-economic conditions have strongly influenced the spatio-temporal extent of this development (Chamberlain et al. 2000, Stoate et al. 2009, Tryjanowski et al. 2011, Fartmann et al. 2021). While in large parts of Central and North-western Europe, species-rich habitats shrunk to small areas due to the massive intensification of agriculture under the EU's Common Agricultural Policy (CAP) since the mid-20th century, the newer EU member states of Central and Eastern Europe (CEE) are characterised by a lower land-use intensity on average to date (Báldi & Batáry 2011, EEA 2015). As a result, there are comparatively large areas of HNV farmland remaining in these countries. Therefore, many rare species associated with agricultural habitats still frequently occur throughout the CEE states (Reif et al. 2024). However, their populations are increasingly threatened by recent alterations in human land use (EEA 2012, Stoate et al. 2009).

Halting the decline of habitat and biodiversity loss in Europe is addressed by the EU Habitats Directive and the EU Birds Directive. The overall objective of these conservation policy tools is to ensure that legally protected habitat types (listed in Annex I of the EU Habitats Directive) and species of European conservation concern (e.g. species listed in Annexes II and IV of the EU Habitats Directive or Annex I of the EU Birds Directive) are maintained or restored to a favourable conservation status in the long term. For this purpose, the Natura 2000 system was created as a pan-European network of protected areas. There is a legal obligation of EU member states to take measures to achieve the objectives of these EU directives for biodiversity conservation.

1.2 Land-use change and biodiversity in Hungary

With 28% of the country's land area, the proportion of HNV farmland in Hungary is currently almost twice as high as in Germany (Paracchini et al. 2008, EEA 2012). Although the collectivisation of agriculture in former socialist Hungary (1949–1989) also had a negative impact on biodiversity (Báldi & Batáry 2011), due to mostly inefficient farming methods, the extent of biodiversity loss in the agricultural landscape was far less dramatic than in many other parts of Europe (cf. Donald et al. 2001, Donald et al. 2006). The collapse of collective agriculture at the beginning of the 1990s led to large-scale abandonment of arable land and grassland areas in Hungary (Biró et al. 2013, Mihók et al. 2017). This even resulted in short-term positive population trends for some species characteristic of agricultural landscapes (Verhulst et al. 2004, Gregory et al. 2005, Donald et al. 2006, Báldi & Batáry 2011, Tryjanowski et al. 2011). Therefore, the conservation status of many farmland species in Hungary is still better than the European average today (Báldi & Batáry 2011, Keller et al. 2020). The European Roller (*Coracias garrulus*), for example, has suffered massive population declines across Europe, but more than 2,000 breeding pairs of this insectivorous species can still be found in Hungary (Szép et al. 2022).

When joining the EU in 2004, Hungary agreed to implement the CAP and the EU biodiversity directives. While habitat and biodiversity loss in Central and North-western Europe has at least slowed down over the last 30 years thanks to intensified conservation measures (e.g. Carvalheiro et al. 2013, Löffler et al. 2020), the situation is somewhat different in Hungary. Recent studies show that the changed agricultural production methods resulting from agricultural privatisation in the 1990s and especially from the implementation of the CAP are increasingly endangering the biodiversity in Hungarian agricultural landscapes (Báldi & Faragó 2007, Szép et al. 2012, Biró et al. 2013, Mihók et al. 2017). While land use has mostly been intensified on productive soils, Hungary's agricultural habitats on marginal land have often been left fallow. Both are known to cause declines in farmland biodiversity in the long term (Fartmann et al. 2021). Accordingly, Reif et al. (2024) detected a severe decline of farmland birds in new EU member states, including Hungary, after their EU accession. This development has especially been driven by the large-scale loss of low-intensity farming practices.

Figure 1: Many farmland birds, such as the European Roller (*Coracias garrulus*), have suffered severe declines over the last decades. While this insectivorous bird species is extinct in Germany and Austria, viable populations still exist in some of the newer EU Member States of Central and Eastern Europe, including Hungary with more than 2,000 breeding birds of this species listed in Annex I of the EU Birds Directive. (Photo: Franz Löffler)

In particular, livestock grazing, which has traditionally played a central role in Hungarian agriculture and is known to be beneficial for many farmland specialists, suffered a severe decline across the country (Figure 2, Báldi & Faragó 2007, Varga et al. 2016, HCSO 2025). These developments contradict the goals of the EU Habitats and Birds Directives that Hungary committed to when it joined the EU. Since the implementation of the Habitats and Birds Directives began in Hungary in 2007, 21% of the Hungarian territory has already been designated as Natura 2000 sites. Despite conservation-related EU funds being generally available for the management of Natura 2000 sites (EC 2019), effective management measures are still lacking in many of these sites in Hungary. On the one hand, this is due to insufficient knowledge about the occurrence of species and their ecology in Natura 2000 sites. On the other hand, it is likely that the local socio-economic conditions make it difficult to implement habitat management. For example, in Hungary, the number of farmers that could implement measures in the context of EU agri-environmental schemes has declined dramatically over the last decades (Mihók et al. 2013). In addition, information is needed about the potential advantages of such nature-friendly farming schemes for farmers. For example, land users should be informed about funds available for managing their land in a nature-friendly way. Practical experience has shown that nature conservation can only succeed if the interests of different stakeholders are taken into account (Farwig et al. 2025). This underlines the importance of collaborations between conservationists and land users, such as farmers and foresters.

Figure 2: Livestock grazing has traditionally played a central role in Hungarian agriculture. However, since implementing the CAP, the number of grazing animals has fallen strongly with severe effects on Hungary's farmland biodiversity. A revival of low-intensity grazing would be highly beneficial to biodiversity conservation. (Photo: Thomas Fartmann)

1.3 Advisory assistance for biodiversity conservation

Within the scope of the Advisory Assistance Programme (AAP) of the German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN), recommendations for habitat management in dry calcareous grasslands in Hungary were developed as part of a collaborative project, using the example of the Natura 2000 site Vértes (see Chapters 2.1 and 2.2). These recommendations were derived from a thorough survey of the biodiversity of four indicator groups and the local habitat conditions in 40 study plots, representative of dry calcareous grasslands in the project region (see Chapter 2.3). Though these grassland plots were still characterised by a very high biodiversity, including a considerable number of species protected by the EU Habitats or Bird Directive, measures to maintain these habitats and species in a favourable conservation status are restricted to small areas to date. To establish effective conservation measures, first a thorough understanding of the environmental factors driving biodiversity in the target habitats is needed. For this purpose, we conducted an ecological analysis of the biodiversity data of dry calcareous grasslands in the project region. With the involvement of local conservationists, scientists, farmers, and landowners, recommendations for potential conservation measures in these priority habitats for European biodiversity conservation were developed based on these analyses.

2 Biodiversity in the Vértes Hills

2.1 Project region

The project region comprised the Vértes Hills, located 60 km south-west of Budapest, forming part of the north-eastern Transdanubian Mountains (Figure 3). The Vértes Hills, which rise to almost 500 m above sea level, are dominated by dolomite and limestone rocks, while loess sediments are characteristic of their foothills. Belonging to the forest steppe biome, this region has a continental climate with an average annual temperature of 9.5 °C and low precipitation, usually not exceeding 600 mm per year (Budai & Fodor 2008, Dövényi 2010). While the climate in the south-eastern part of the Vértes Hills is sub-mediterranean, the central and northern part is more submontane. Since these conditions make the project region an important biodiversity hotspot, the Vértes Hills have been designated as a Natura 2000 site (HUDI 30001) in 2004.

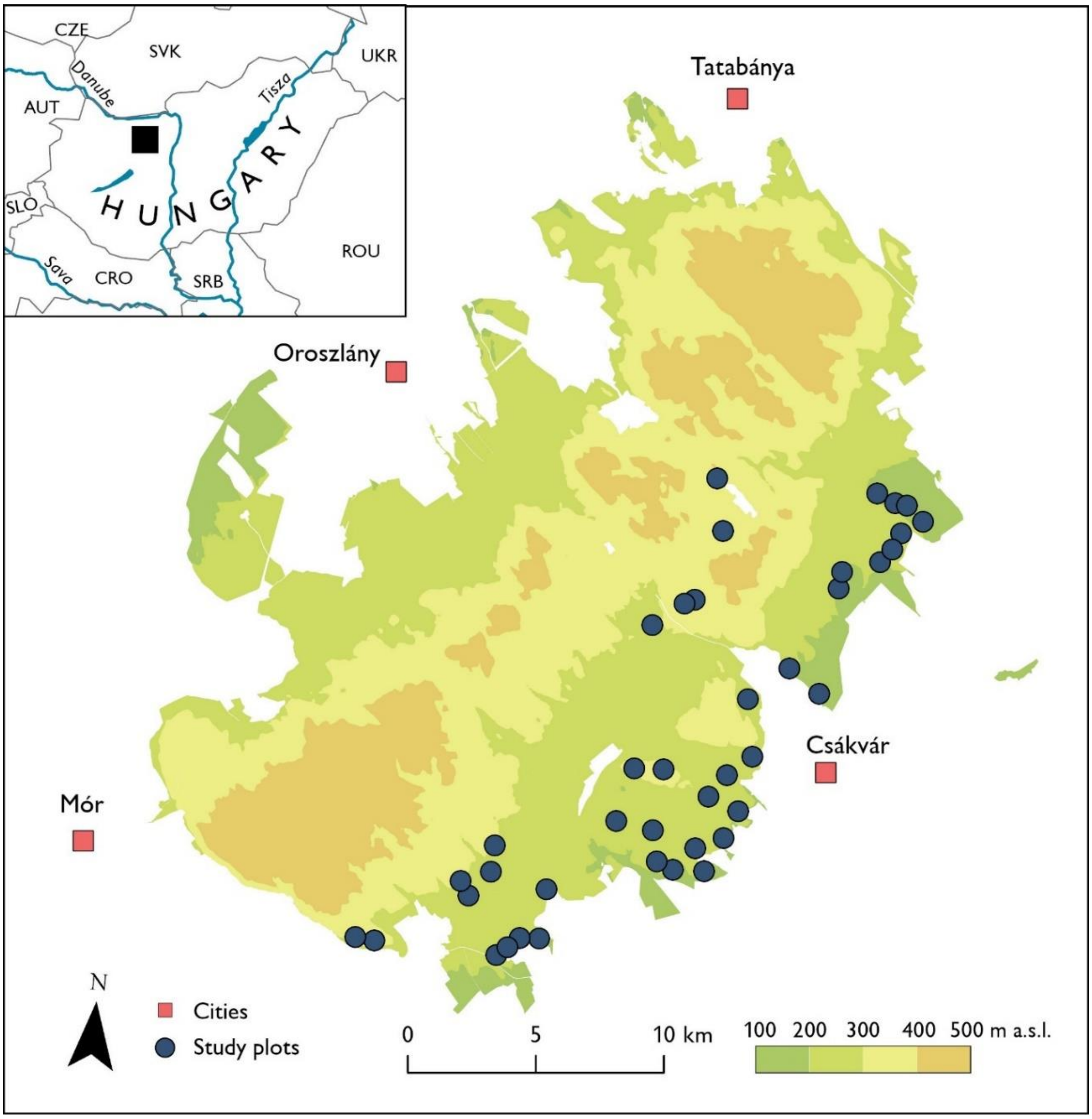

Figure 3: Location and boundaries of the Natura 2000 site Vértes (HUDI 30001) in Hungary as well as the location of the 40 study plots in dry calcareous grasslands in the project region. (Map illustration by Franz Löffler based on data provided by OpenStreetMap, 2026)

2.2 Target habitats and land-use history

The south-eastern part of the Vértes Hills is characterised by large areas of dry calcareous grasslands interspersed with open, dry oak forests, contributing to a high habitat heterogeneity at the landscape level (Figure 4). As they are characterised by a high species richness and protected at the European level, they were chosen as target habitats within the project. Although the climatic conditions in the Vértes Hills are favourable for the development of dry grasslands, most of their extent would naturally be dominated by woodland vegetation (cf. Erdős et al. 2022). Without the impact of human land use, grasslands would only cover small areas of their current extent, where the conditions are especially unsuitable for the growth of trees and shrubs. The grasslands have been shaped by herbivore grazing along with other human-induced disturbances, such as burning and shrub-cutting, over millennia (Chytrý et al. 2022, Erdős et al. 2018, 2022). Since they are important strongholds of species richness (e.g. Kevey & Bauer 2014, Janišova et al. 2020, Szép et al. 2022), these grasslands have been protected under Annex I of the EU Habitats Directive as priority habitats for European biodiversity conservation. Among grasslands, the following habitat types cover the largest areas in the Vértes Hills:

(1) >750 ha of sub-Pannonic steppic grasslands (Natura 2000 code 6240),

(2) >450 ha of semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (* important orchid sites, Natura 2000 code 6210) and

(3) >140 ha of rupicolous Pannonic grasslands (*Stipo-Festucetalia pallentis*, Natura 2000 code 6190).

Since these three habitat types form small-scale mosaics within the study plots in the Vértes Hills, they are summarised under the term 'dry calcareous grasslands' in the following.

Until the mid-20th century, the dry calcareous grasslands in the Vértes Hills were used as common pastures, which were used collectively by local shepherds. During this time, up to 20,000 domestic animals grazed in the region, including mainly sheep and cattle, but also horses and pigs (Csőre 1987). Wood pastures were also common in the study area in former times (Varga & Bölöni 2009, Varga et al. 2016). Due to agricultural collectivisation starting in 1961, private farms were converted into state-owned agricultural cooperatives. Although these cooperatives still hold large numbers of livestock, grazing was largely limited to the foothills and plains surrounding the Vértes Hills (Viszló et al. 2019). At the same time, the dry grassland areas on the rocky slopes of the region came under the administration of the state's forestry department with its management instruments. As a consequence of forestry legislation, livestock grazing was prohibited in these areas, even though these sites are mostly unsuitable for producing wood. Following the collapse of collective farming in Hungary in 1990, the number of livestock in the Vértes Hills continued to decline, resulting in the further abandonment of the dry grasslands (Viszló 2010). Along with a decline in hunting pressure, these reforms contributed to strong increases in the local populations of wild ungulates, especially Mouflon, Roe Deer, Red Deer and Wild Boar (Csányi 2012).

Figure 4: The Vértes Hills hold large areas of dry calcareous grasslands protected under Annex I of the EU Habitats Directive (Natura 2000 codes: 6240, 6210 and 6190). These grassland types often build small-scale mosaics characterised by a high degree of habitat heterogeneity and a high proportion of early-successional stages contributing to their outstanding biodiversity. (Photo: Thomas Fartmann)

Despite being legally protected under the EU Habitats Directive, the dry grasslands in the Vértes Hills are largely unmanaged to date. Only a few grasslands, mostly located on more productive soils in the foothills, are used as pastures or meadows. By contrast, wild ungulate stocks in the Vértes Hills are deliberately kept high, because of strong interests of the hunting sector. Although it can be assumed that wild ungulates also prevent the succession of the target habitats, their impact on biodiversity is a subject of controversy among conservationists. Moreover, conflicts with land users are rising, when they become overabundant. Therefore, other measures to prevent succession and maintain the high biodiversity within the dry calcareous grasslands in the Vértes Hills are required.

2.3 Indicator groups and flagship species

As a basis for the recommendations for habitat management of dry calcareous grasslands in the Vértes Hills, data on the biodiversity of the following indicator groups were sampled based on standardised survey methods according to international monitoring standards:

(1) breeding birds,
(2) butterflies and burnet moths,
(3) grasshoppers and
(4) vascular plants.

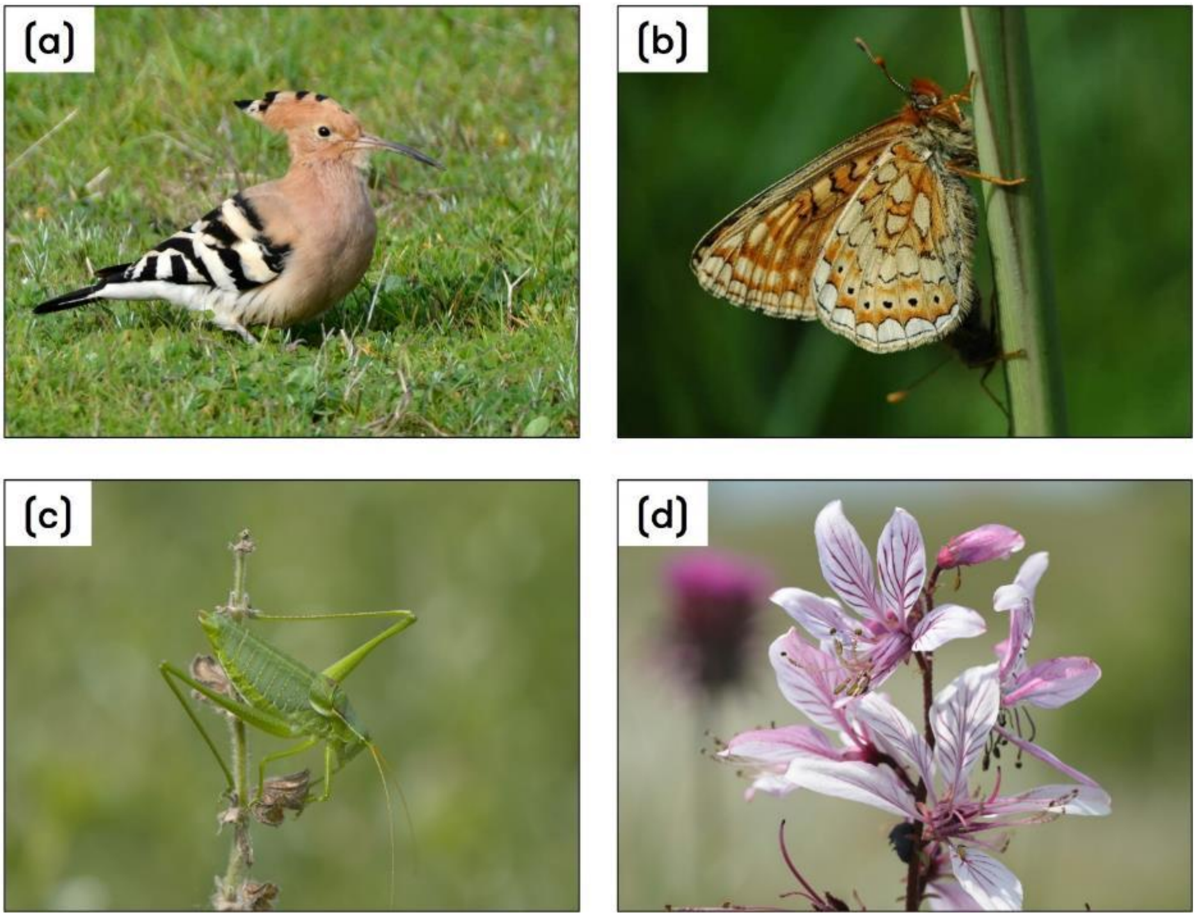

Figure 5: Many species of high conservation concern still frequently occur in the dry calcareous grasslands of the Vértes Hills. These are for example: (a) Hoopoe (*Upupa epops*), (b) Marsh Fritillary (*Euphydryas aurinia*), (c) Keeled Plump Bush-cricket (*Isophya costata*) and (d) Common Diptam (*Dictamnus albus*). (Photos: Thomas Fartmann)

All four groups show exceptionally high species diversity in the dry calcareous grasslands in the Vértes Hills and are surrogates for their overall biodiversity. They are all highly sensitive to environmental changes, especially in relation to land use. However, the ecological requirements differ among the species groups. While the occurrence of plants and grasshoppers is primarily determined by habitat quality within grasslands, the biodiversity of butterflies and birds additionally depends on factors at the landscape level, such as sufficient habitat size and connectivity (Poniatowski et al. 2018, Brüggeshemke et al. 2022). Moreover, the selected species groups are characterised by differences in their reproduction and foraging strategies. Therefore, they are well suited to derive effective recommendations for habitat management as far as possible promoting overall biodiversity. Moreover, the selected indicator groups are also popular among the public, making them appropriate for raising awareness of biodiversity conservation. In particular, species of European conservation concern should be given particular attention in the implementation of habitat management. A considerable number of species protected by the EU Habitats or Birds Directive can still frequently be found in the Vértes Hills (Figure 5 and Table 1). In addition to the species listed in Annexes II or IV of the EU Habitats Directive or in Annex I of the Birds Directive, other species that have declined sharply across Europe in recent years may also be considered as flagship species for biodiversity conservation.

Table 1: Species protected under the EU Habitats Directive (HD: Annexes II and IV) or EU Birds Directive (BD: Annex I), their European threat status (Bilz et al. 2011, BirdLife International 2021, Hochkirch et al. 2016, van Swaay et al. 2010) and their frequency (%) in the study plots in the Vértes Hills

Species		Taxon	EU HD or BD	Red List Europe	Red List EU 27	Frequency (%)
Common name	**Scientific name**					
Woodlark	*Lullula arborea*	Birds	I	LC	LC	85
Clouded Apollo	*Parnassius mnemosyne*	Butterflies	IV	NT	NT	70
Red-backed Shrike	*Lanius collurio*	Birds	I	LC	LC	59
European Nightjar	*Caprimulgus europaeus*	Birds	I	LC	LC	51
King Stephen's Feathered Pink	*Dianthus plumarius* ssp. *regis-stephani*	Plants	II/IV	LC	LC	48
Low Iris	*Iris humilis* ssp. *arenaria*	Plants	II/IV	DD	DD	45
Hungarian Mountain Fennel	*Seseli leucospermum*	Plants	II/IV	DD	DD	30
Collared Flycatcher	*Ficedula albicollis*	Birds	I	LC	LC	29
European Turtle Dove	*Streptopelia turtur*	Birds	I	VU	NT	25
Tawny Pipit	*Anthus campestris*	Birds	I	LC	LC	24
Black Woodpecker	*Dryocopus martius*	Birds	I	LC	LC	17
Predatory Bush-cricket	*Saga pedo*	Orthoptera	IV	LC	LC	15
Marsh Fritillary	*Euphydryas aurinia*	Butterflies	II	LC	LC*	15
Greater Pasque Flower	*Pulsatilla grandis*	Plants	II/IV	LC	LC	10
Eurasian Toothed Grasshopper	*Stenobothrus eurasius*	Orthoptera	II/IV	LC	EN	8
Barred Warbler	*Sylvia nisoria*	Birds	I	LC	LC	7
European Roller	*Coracias garrulus*	Birds	I	LC	LC	7
Middle Spotted Woodpecker	*Leiopicus medius*	Birds	I	LC	LC	7
Grey-headed Woodpecker	*Picus canus*	Birds	I	LC	LC	7
Stock Dove	*Columba oenas*	Birds	I	LC	LC	7
Syrian Woodpecker	*Dendrocopos syriacus*	Birds	I	LC	LC	5
European Tree Sparrow	*Passer montanus*	Birds	I	LC	LC	5
Keeled Plump Bush-cricket	*Isophya costata*	Orthoptera	II/IV	LC	LC	3
Single-flowered Sawwort	*Serratula lycopifolia*	Plants	II/IV	NT	NT	3

This is particularly the case for species that depend on nutrient-poor habitat conditions and the presence of early-successional stages. The severe decline of these species in European grasslands is primarily due to changes in land use and abandonment of the habitats as well as increased atmospheric nitrogen depositions (Bobbink et al. 2010, Fartmann et al. 2021). Many species of international conservation concern, especially those inhabiting early-successional stages, are still common in the dry calcareous grasslands of the Vértes Hills. Measures to protect these species require a detailed understanding of the environmental factors that drive their populations, which was addressed as part of an ecological analysis (see Chapter 2.4).

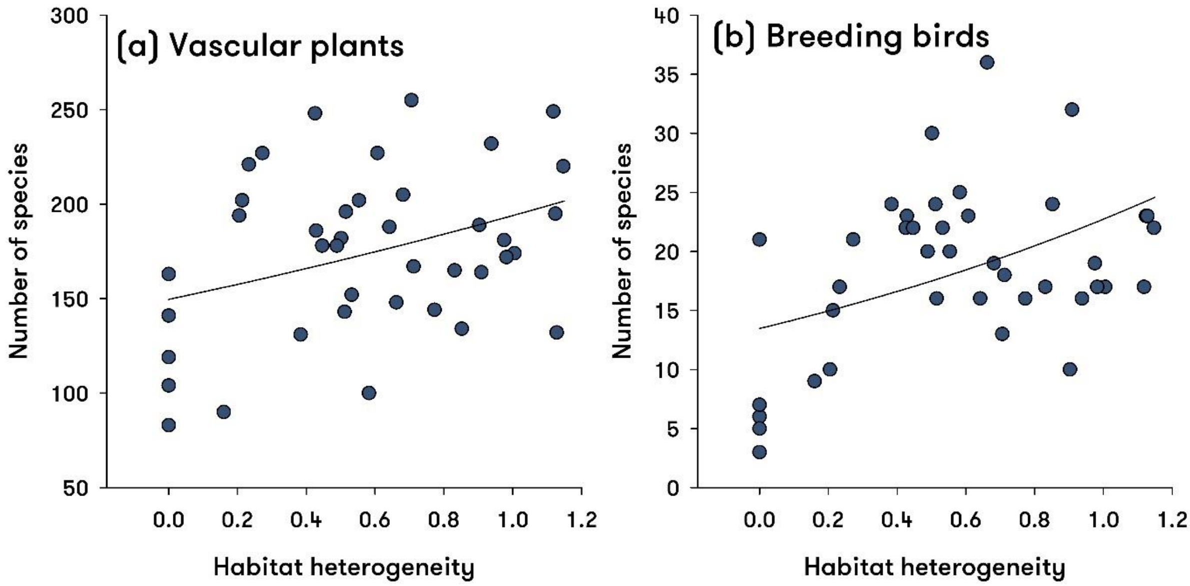

Figure 6: Relationship between the number of species of (a) vascular plants and (b) breeding birds and habitat heterogeneity in dry calcareous grasslands of the Vértes Hills. Their species richness significantly increased with higher habitat heterogeneity. Statistical significances (p) were detected using Generalised Linear Models (GLM): (a) $p < 0.05$, (b) $p < 0.01$.

2.4 Key factors for high biodiversity in the target habitats

The presence of **large-scale and well-connected dry calcareous grasslands** is crucial for the high species diversity and occurrence of threatened species in the Vértes Hills. Larger habitat areas are often more heterogeneous and thus offer niches for a greater number of species (Löffler & Fartmann 2017). They also fulfil the requirements of species inhabiting large territories such as many farmland birds (Brüggeshemke et al. 2022). In addition, some species form metapopulations and require a network of sufficiently large and interconnected habitat areas for their long-term survival (Zulka et al. 2014). A typical example is the **Marsh Fritillary** (*Euphydryas aurinia*), whose occurrence depends not only on the availability of suitable microhabitats for reproduction, but also on sufficient habitat area and high connectivity of grasslands for creating a resilient metapopulation network (Figure 7, Anthes et al. 2003).

Habitat quality and heterogeneity are among the most important drivers of the biodiversity of dry grasslands (Poniatowski et al. 2018, Fartmann et al. 2021). Overall, the analyses of the biodiversity data sampled in the Vértes Hills revealed that a high habitat heterogeneity within the grassland plots was particularly beneficial for overall species richness. Habitat heterogeneity is associated with higher microhabitat diversity within grasslands, which usually contributes to higher plant and animal diversity (Schwarz et al. 2018, Fartmann et al. 2021, Brüggeshemke et al. 2022, Fumy & Fartmann 2023). In the dry calcareous grasslands of the Vértes Hills, this was particularly true for the species richness of breeding birds and vascular plants (Figure 6).

On the one hand, habitat heterogeneity within the grasslands was promoted by the **presence of shrubs and the proximity to open woodlands,** which, for example, provided suitable nesting sites for shrub- or cavity-nesting bird species (Figure 8).

Figure 7: The Marsh Fritillary (*Euphydryas aurinia*) is a butterfly species, which has suffered severe population declines throughout Europe. In the Vértes Hills, this species listed in Annexes II and IV of the EU Habitats Directive benefits from the large-scale network of dry calcareous grasslands. (Photo: Thomas Fartmann)

The **Red-backed Shrike** (*Lanius collurio*), for example, benefits from hedgerows and bushes used for breeding close to open grasslands with sufficient insect prey. Species associated with deciduous woodlands with a high amount of deadwood, such as the **Collared Flycatcher** (*Ficedula albicollis*) or several woodpeckers, were also found frequently in the grassland plots in the Vértes Hills (Figure 9). Moreover, the large-scale presence of **ecotones between grasslands and woodlands** additionally favoured the occurrence of plant and insect species associated with fringe vegetation within the dry calcareous grassland in the Vértes Hills (cf. Konvička et al. 2006). For example, the **Clouded Apollo** (*Parnassius mnemosyne*), which is declining across Europe, is still a common butterfly in this area. Smooth transitions between woodlands and open habitats are also of outstanding importance for preserving numerous plant species characteristic of thermophilic fringes, such as the **Common Diptam** (*Dictamnus albus*).

On the other hand, **sparsely vegetated patches with short swards** and a **high proportion of bare ground or gravel** also increased the structural richness within the dry calcareous grasslands in the Vértes Hills. The maintenance of such structures is closely linked to ecological disturbance, mostly provided by human land use. As species that depend on **early-successional stages** are overrepresented in the national and pan-European red lists, the presence of these habitat structures is essential for biodiversity conservation, especially for threatened taxa.

Figure 8: Open, sunlit woodlands, which are characterised by a high habitat heterogeneity, offer suitable habitats for a variety of both forest and grassland species. The high amount of standing deadwood is also important for many species, including cavity-nesting birds. (Photo: Jonas Brüggeshemke)

Figure 9: The Collared Flycatcher (*Ficedula albicollis*) listed in Annex I of the EU Birds Directive inhabits open woodland and forest edges as well as grasslands with scattered trees. The species requires old trees and a high amount of standing deadwood offering nest holes for breeding. (Photo: Franz Löffler)

In dry calcareous grasslands, especially low-competitive and thermophilic species, which often have become scarce in Europe's agricultural landscapes, depend on the presence of early-successional stages. For instance, the occurrences of the **King Stephen's Feathered Pink** (*Dianthus plumarius* ssp. *regis-stephani*) and the **Hungarian Mountain Fennel** (*Seseli leucospermum*) in the Vértes Hills were largely restricted to south-facing rocky grasslands on shallow soils with a high proportion of gravel and bare ground (Figure 10). In addition to the poor edaphic conditions, such structures are also promoted by grazing, trampling or rooting of wild ungulates. They were therefore mostly found in areas where the abundance of ungulates was high. Patches of bare ground are especially important for the germination of light-demanding plant species, such as the aforementioned. At the same time, they also provide suitable microhabitats for a wide range of xerothermophilic insect species (Fartmann et al. 2012, Konvička et al. 2021). As demonstrated for the **Marsh Fritillary** (*Euphydryas aurinia*), patches of bare ground provide a warm microclimate required for the successful development of the immature stage of this species (Scherer et al. 2025). Another example is the **Predatory Bush-cricket** (*Saga pedo*), which was found in rocky dry grasslands with a heterogeneous mosaic of bare ground and denser vegetation (Figure 11). The first is required for oviposition and the development of thermophilic nymphs, while the latter provides the adults with shelter from predators. Although both species are still present in the dry calcareous grasslands of the Vértes Hills, a future decline can be expected as succession progresses, especially in dry grasslands on more productive soils, when habitat management is lacking in the long term (Krištín & Kaňuch 2007, Scherer et al. 2025).

Figure 10: The Hungarian Mountain Fennel (*Seseli leucospermum*) is endemic to Hungary and listed in Annexes II and IV of the EU Habitats Directive. The species occurs in sun-exposed rocky dolomite grasslands, where succession speed is low. It occurred in almost one third of the study plots in the Vértes Hills. (Photo: Sándor Bérces)

Figure 11: The Predatory Bush-cricket (*Saga pedo*) is listed in Annex IV of the EU Habitats Directive. The species prefers rocky grasslands providing heterogeneous mosaics of bare ground and dense vegetation. (Photo: Sándor Bérces)

Figure 12: Many insectivorous bird species depend on early-successional stages for foraging. The Northern Wheatear (*Oenanthe oenanthe*) was restricted to grazed sites with short swards with a high proportion of bare ground and nesting cavities in rocks. (Photo: Thomas Fartmann)

Ongoing succession would also be detrimental to the majority of bird species characteristic of the dry calcareous grasslands of the Vértes Hills. Many farmland birds vitally depend on the presence of bare ground in their breeding habitats (Fartmann et al. 2018, Brüggeshemke et al. 2025). The lack of suitable foraging habitats along with a decline in insects is one of the main reasons for the scarcity of the species in large parts of Europe. This is because most farmland birds feed on insects taken directly from the ground or from vegetation close to the ground. As the accessibility of food is even more important to farmland birds than its abundance (Newton 2017, Vickery & Arlettaz 2012), the presence of early-successional stages in grasslands is crucial for their conservation. Charismatic examples include the **Woodlark** (*Lullula arborea*), the **Northern Wheatear** (*Oenanthe oenanthe*) or the **Tawny Pipit** (*Anthus campestris*), which all depend on patches of short vegetation or bare ground for foraging and are still common breeders in the Vértes Hills (Figure 12).

However, as the habitat preferences differ among species, habitat management should also aim to preserve **mid-successional stages** of grasslands. It has been shown that the overall abundance of insects in grasslands usually peaks in intermediate successional stages (Fartmann et al. 2012). Unlike the early-successional stages of the dry calcareous grasslands in the Vértes Hills, mid-successional stages are characterised by a **higher vegetation cover and biomass** as well as an **increased abundance of flowers (**Figures 13 and 14). In contrast to late-successional stages (Figure 15), they are still characterised by a microclimate suitable for a wide range of species typical of dry calcareous grasslands. In the analyses of the biodiversity data, it has been found that butterfly species richness in the dry calcareous grasslands of the Vértes Hills was positively affected by a **medium amount of bare ground and higher shrub cover**, which are characteristic of mid-successional stages. Overall butterfly abundance peaked in plots with a **higher litter and moss cover** characteristic of grassland exhibiting a low land-use intensity. While the larvae of many butterfly species depend on a warm microclimate, adults require flower-rich grasslands providing a high nectar abundance. Such conditions are most likely to be met in mid-successional stages. The same applies to phytophilous species of other insect taxa. For example, the **Keeled Plump Bush-cricket** (*Isophya costata*) requires taller vegetation, which is most likely to be found in mid-successional stages characterised by an intermediate level of ecological disturbance (Bauer & Kenyeres 2006, Kenyeres & Bauer 2021). The **ecotones between forests and grasslands**, as mentioned above, also often meet the requirements of species of mid-successional stages. However, if left unmanaged over the long term, succession would progress towards dense shrubs or closed forests. This would very likely result in the loss of grassland-typical species and a decline in overall biodiversity in the Vértes Hills.

Based on these findings, it can be concluded that the maintenance of high biodiversity in general and a favourable conservation status of the target habitats and flagship species protected under the EU Habitats Directive depends on three factors:

(1) the presence of **large-scale and well-connected dry calcareous grasslands,**
(2) a **high habitat quality and heterogeneity** within grassland patches and
(3) the maintenance of **early- and mid-successional stages**.

Figure 13: Early-successional stages of dry calcareous grasslands are characterised by a high proportion of bare ground or gravel. They provide microhabitats for a wide range of low-competitive plant and thermophilic insect species. (Photo: Franz Löffler)

Figure 14: Mid-successional stages of dry calcareous grasslands are characterised by a higher biomass and abundance of pollen and nectar sources. A high abundance of flowering plants, such as the Vipers' Bugloss (*Echium vulgare*), promotes the overall density of pollinating insects, such as butterflies. (Photo: Thomas Fartmann)

Figure 15: Late-successional stages of dry calcareous grasslands are subject to encroachment of grasses and shrubs. They are usually characterised by a lower biodiversity. (Photo: Zoltán Kenyeres)

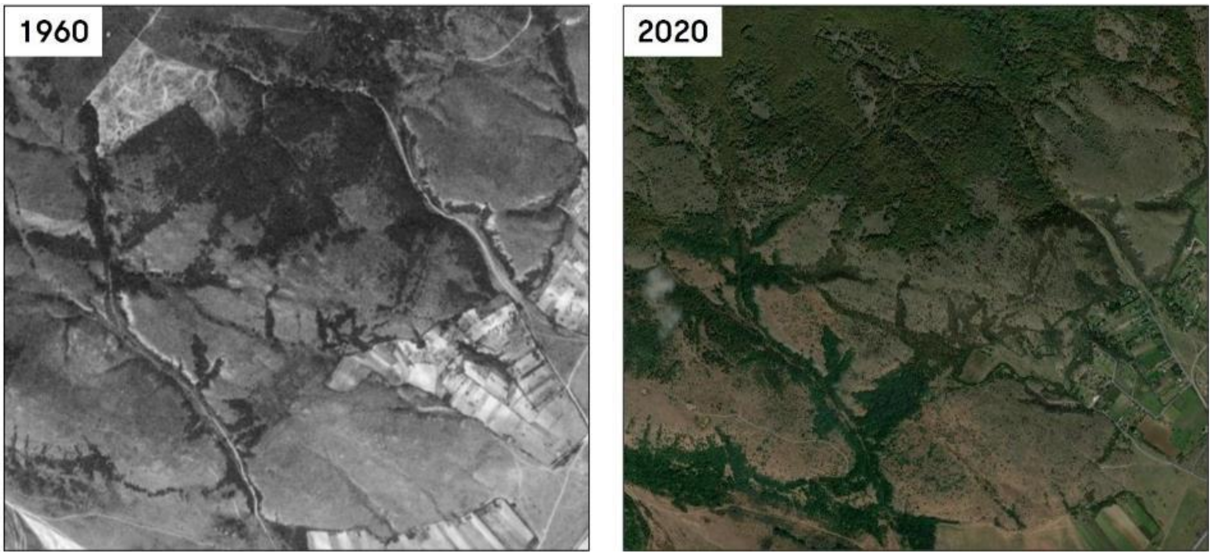

Figure 16: Aerial photographs show the extent of dry calcareous grasslands south-east of Gánt in the 1960s and 2020s (south-eastern Vértes Hills). Succession has caused a substantial decline in the area and connectivity of these habitats of international conservation concern. (Image source: https://maps.arcanum.com)

In order to secure these habitat conditions in the long term, measures for habitat management must be established. Based on the results of the ecological analysis, we have derived technically sound proposals for habitat management in dry calcareous grasslands in the following (see

Chapters 3.1 to 3.5). However, their feasibility also depends on a number of socio-economic factors, which are addressed in Chapter 3.6.

3 Recommendations for habitat management

3.1 Maintaining large-scale habitat networks

The large-scale occurrence of well-connected habitats is a basic prerequisite for high biodiversity in grasslands (Poniatowski et al. 2018, Fartmann et al. 2021). Even though the dry calcareous grasslands in the Vértes Hills currently still cover large areas, a consistent implementation of EU environmental law in Hungary must ensure that they are not destroyed by human interventions or by abandonment. The implementation of the EU Habitats Directive falls within the remit of the Hungarian Ministry of Public Administration and Rural Development. This institution has to ensure that any planned interventions must be accompanied by Habitats Directive impact assessments and compensated for in advance when being implemented. In former times, prior to the designation as Natura 2000 site, some dry calcareous grasslands in the Vértes Hills were afforested with non-native trees, mainly Black Pine (*Pinus nigra*). In addition, a small proportion of dry grasslands has been lost due to mining of bauxite and dolomite in the past. Today, dolomite is still actively mined adjacent to protected grasslands. In light of these potential pressures, the **further afforestation of grasslands and the expansion of mineral extraction sites or other industrial infrastructure at the expense of dry grassland areas in the Vértes Hills has to be avoided**. Despite a small proportion of shrubs and other woody features increases the habitat heterogeneity in dry calcareous grasslands, shrub encroachment due to succession is also causing a gradual reduction in the area and quality of these habitats. This is especially true for areas where grazing is lacking or the intensity of land use is too low to prevent succession. Even in edaphically poor areas with a low succession speed, such as the rocky dry calcareous grasslands in the Vértes Hills, there is a risk of habitat loss in the long term. Therefore, the **proportion of shrubs and trees within dry grasslands should be limited to an area between 10% and a maximum of 20%** (Wiesbauer 2009, Wiesbauer 2013). Historical aerial photographs show that the dry grassland areas in the Vértes Hills have already shrunk significantly since they have become abandoned in the mid-20th century (Figure 16). In some grassland areas, the proportion of woody plants has already exceeded the specified limit. Therefore, **measures to counteract the negative impacts of ongoing succession on biodiversity are urgently needed**.

3.2 Maintaining habitat heterogeneity and quality by livestock grazing

Habitat management in grassland habitats should be geared towards maintaining a favourable habitat quality for as many species as possible. Since species typical of dry calcareous grasslands can have different habitat requirements, **the focus of management measures should be on increasing habitat heterogeneity** (Erdős et al. 2018, Fartmann et al. 2021). Such conditions can be achieved through **extensive grazing with low stocking densities over large areas** (Török et al. 2016, Schwarz & Fartmann 2022, Becker et al. 2025). This form of land use corresponds to the influence of wild herbivores in the natural grassland habitats of the Eurasian steppes. Due to the large size of the dry calcareous grasslands in the Vértes Hills, **year-round grazing with less than 0.2 livestock units per hectare** would be a highly recommendable option for habitat management in the dry calcareous grasslands from a scientific point of view (Bunzel-Drüke et al. 2008, Köhler et al. 2016). This would likely **maintain a habitat mosaic with different successional stages side by side**. Since open woodlands are also of great importance for biodiversity (Fartmann et al. 2013), year-round grazing systems should ideally also include wood pastures adjacent to the dry calcareous grasslands, provided that this is in line with current forestry legislation in the Vértes Hills (Plieninger et al. 2015, Varga et al. 2016). Although year-round grazing generally involves less effort and costs than temporary, small-scale grazing, the implementation of year-round grazing systems is often challenging due to local structural conditions, such as the high land requirements (>50 ha) and the differing interests of landowners (Bunzel-Drüke et al. 2008, Fartmann et al. 2021, also see Chapter 3.6).

Therefore, **smaller-scale implementation of grazing** also should be considered for the habitat management of dry calcareous grasslands. A **mosaic-like approach** should be used for small-scale grazing. This means that **grazing should vary spatially and temporarily and should not be carried out with the same intensity in all areas** of dry calcareous grasslands. This ensures that **different successional stages can coexist** within grassland patches, which contributes to increased habitat heterogeneity (Schirmel et al. 2010). As they are of prime importance for the conservation of threatened species, the frequency and intensity of grazing should be adjusted to **maintain early-successional** stages (Fartmann et al. 2012). For this purpose, **short grazing periods with higher stocking rates in early spring** are well suited to maintain early-successional stages (Becker et al. 2025). This is mainly because grasses can be effectively suppressed by grazing in early spring or during the winter half-year, thereby promoting less competitive species (Köhler et al. 2016, Zahn et al. 2022, Angerer et al. 2023, Fartmann et al. 2025).

Furthermore, the **intensity of grazing should be adapted to the productivity of the grasslands** (Wiesbauer 2013). For example, rocky dry calcareous grasslands on shallow soils require only low grazing pressure due to their low succession speed. On those sites, grazing at intervals of two to five years is sufficient. In contrast, dry calcareous grasslands on deeper soils require more regular grazing intervals, as they would otherwise rapidly become overgrown by shrubs. They therefore should be grazed more frequently. If grazing is carried out for short periods (<1 month), higher stocking densities up to two livestock units per hectare can be tolerated (Bunzel-Drüke 2008). In abandoned dry grasslands, more intensive grazing is recommended during the first few years after the reintroduction of grazing. Once the habitats have reached a good conservation status, the stocking density of grazing animals should be reduced to a lower level (Becker et al. 2025).

In addition to the frequency and intensity of grazing, the **type of livestock** should also be considered when implementing habitat management. It is generally differentiated between three **feeding-strategy types** of grazing animals: browsers, intermediate feeders and true grazers (Bunzel-Drüke 2008). While **browsers** and **intermediate feeders** exhibit selective feeding towards particularly nutritious plants, **grazers** mainly feed on grass. They therefore have different impacts on the habitat structure of grasslands. In particular, **grazers are well suited to effectively**

prevent succession and promote low competitive plant and insect species. As only a few dry calcareous grasslands in the Vértes Hills are currently grazed by domestic livestock, succession is currently mainly prevented by the high abundance of wild ungulates (cf. Riesch et al. 2019, Figure 17). These mainly comprise browsers (Roe Deer) and intermediate feeders (Red Deer and Mouflon) as well as omnivores (Wild Boar). However, wild grazers, such as Aurochs, Wild Horses or European Bison (which were common in ancient times, Erdős et al. 2018) as well as their domestic counterparts are largely lacking from the dry grassland ecosystems in the Vértes Hills. This imbalance can lead to a dominance of grasses at the expense of low-competitive species (Bunzel-Drüke et al. 2008). In addition, there is a risk of overgrazing when the populations of wild ungulates become too high. Their impact on biodiversity is therefore subject of controversial debates among conservationists (Beneš et al. 2006, Kenyeres et al. 2020, Konvička et al. 2021). Moreover, the high abundance of wild ungulates often raises conflicts with other local stakeholders, including farmers and foresters.

Therefore, from an integrative conservation perspective, low-intensity grazing with domestic livestock, along with careful population management of the wild ungulate population, should be aimed for in the future management of the dry calcareous grasslands in the Vértes Hills. The **composition of grazing animals should be based on the traditional ecological knowledge about the land use in a region** (Varga et al. 2020). According to information on the traditional land use in the Vértes Hills, sheep and goats as well as cattle, donkeys and horses as true grazers, should be considered for grazing to facilitate biodiversity conservation (Figure 18).

Figure 17: Wild ungulates such as Red Deer (*Cervus elaphus*) occur in high abundance in the Vértes Hills. These herbivores with an intermediate feeding strategy can slow down shrub encroachment in abandoned grasslands but can also raise conflicts both in terms of conservation and land use. (Photo: Franz Löffler)

Figure 18: Low-intensity grazing with local livestock breeds, such as Hungarian Grey Cattle, would likely be beneficial for biodiversity conservation in dry calcareous grasslands. As they promote the occurrence of low-competitive plant and insect species, true grazers should be involved in grazing concepts. (Photo: Hannah Kalthoff)

Sheep and goats are generally well suited **for grazing of low-productive dry calcareous grasslands**, also known as marginal land, while **cattle, donkeys and horses** should be **considered for the grazing of more productive grasslands.** Since they are adapted to the local biogeographic conditions, **local livestock breeds** (e.g. Hungarian Grey Cattle, Nonius or Przewalski Horse, Racka Sheep) should be preferred for grazing (Bunzel-Drüke 2008). Cattle, donkeys and horses, as true grazers, have the advantage over sheep in that they do not feed selectively on herbs and can effectively counteract grass dominance in dry grasslands (Becker et al. 2025). In contrast, sheep grazing can lead to grass dominance when the animals graze exclusively in summer. This usually results in species-poor stands, which also offer only limited habitat suitability for insects (Becker et al. 2025, Fartmann et al. 2025). Goats are particularly well suited to counteracting shrub encroachment, as they browse woody plants very effectively (Elias & Tischew 2016).

3.3 Maintaining habitat quality by mowing or prescribed burning

In contrast to livestock grazing, mowing can lead to an increased abundance of grasses, while low-competitive light-demanding herb species often suffer declines in the long term (Ellenberg & Leuschner 2010). Additionally, mowing typically leads to lower structural richness of grasslands compared to grazing and is hardly applicable on steep slopes (Becker et al. 2025). Nevertheless, **where grazing is difficult** for practical reasons (e.g. lack of grazing animals in a region), **low-intensity mowing can be an alternative tool** in the management of dry calcareous grasslands (Fartmann et al. 2025). Due to the steep terrain interspersed with rocky ridges and the low productivity of most dry grasslands, large-scale mowing is only applicable in a few areas of the Vértes Hills with deeper soils, which are suitable for hay production (e.g. those on loess ground in the foothills). On smaller scales, mowing can be a **valuable option** in specific cases, for example **in combating invasive species**, such as the Goldenrod (*Solidago* ssp.). However, in contrast to grazing, mowing immediately changes the vegetation structure of grasslands with severe effects on many insect species. It is therefore important to **keep uncut refuges covering at least 5 to 20% of the grassland patches** to secure a high abundance of insects (Schwarz et al. 2023). Firstly, such refuges would not be affected by harvest-related insect losses, and they would ensure a continuity in food resources, a balanced microclimate and shelter against predators. Secondly, they would serve as important refuges for insects emigrating from the mown parts of dry grassland meadows (Kenyeres & Varga 2023). Other taxa, such as birds, have also been shown to benefit from uncut refuges (Schoof et al. 2024). To avoid nest losses of ground-nesting birds, **large-scale mowing should only be done outside the breeding season (from mid-June).** Moreover, the **use of biodiversity-friendly mowing techniques** can help to reduce the mortality of animals during mowing (Kenyeres & Varga 2023, Schoof et al. 2024). As some authors have shown, **prescribed burning** can also be an alternative for managing dry grasslands (Ruprecht et al. 2013, Valkó et al. 2014, Valkó & Deák 2021). As fire has played a crucial role in the development of forest-steppe habitats throughout history (Erdős et al. 2022), many species typical of dry calcareous grasslands are well adapted to this factor. Burning destroys the vegetation and the litter layer of grasslands. This creates patches of bare ground that are crucial for species needing early-successional stages (Brüggeshemke et al. 2025).

Figure 19: The application of biodiversity-friendly mowing techniques, such as the use of bar mowers with insect repellents, aims to make a positive contribution to biodiversity in grasslands. Even more important is the availability of uncut refuges within meadows and the timing of mowing. (Photo: Thomas Fartmann)

Competitive grasses can also be suppressed through burning (Kahlert et al., 2005). Although this practice was once widespread in Europe's dry grasslands, including those of the Vértes Hills, it is now rarely employed. To keep losses of insects due to burning within tolerable limits, burning should be **restricted to small areas of covering not more than 20% of grassland patches (maximum area 1 ha)** and **carried out carefully accompanied by fire protection measures to prevent the fire from spreading to other areas (e.g. forests and villages).** Thus, it has still rarely been applied in modern habitat management of dry calcareous grasslands to date (Valkó & Deák 2021).

3.4 Preventing succession by shrub cutting

Shrub encroachment severely threatens the biodiversity of dry calcareous grasslands, including those in the Vértes Hills. In particular, **invasive tree species** such as the Tree of Heaven (*Ailanthus altissima*), Black Locust (*Robinia pseudoacacia*) and Black Pine (*Pinus nigra*) can become problematic. Although these non-native species, except for Black Pine, still rarely occur in the dry grasslands of the Vértes Hills, they require special attention and if necessary, control measures combating them. However, also native species such as the European Smoketree (*Cotinus coggygria)* can contribute to the rapid shrub encroachment of dry grasslands and to a rapid reduction in the habitat area of dry grasslands (Erdős et al. 2013), which is also the case on some sites in the Vértes Hills (Figure 20). Shrub cutting to preserve pastures is a very old practice in dry grasslands (Fartmann 2004, Wiesbauer 2013). The removal of shrubs and young trees leads to higher radiation and thus secures a suitable microclimate for xerothermophilic animal and plant species characteristic of dry calcareous grasslands (e.g. Helbing et al. 2015). Shrub cutting can be done **by hand or**, where possible, **by forest machinery** (Figure 21). In many cases, the effective removal of shrubs is very time-consuming, depending on their extent and species composition. However, the cut material can be processed into wood pellets for bioenergy use, thereby reducing the additional costs incurred (Conrady et al. 2013, Helbing et al. 2015). To ensure the success of the shrub cutting, it is necessary to follow up with extensive grazing (Wiesbauer 2013, Helbing et al. 2015).

3.5 Monitoring the effects of habitat management

A **standardised monitoring** of biodiversity is necessary **in order to track the development of populations of protected species and their habitats**. It is also well suited to **evaluate the effects of habitat management** and to **identify needs for adaptations**. The biodiversity data collected as part of the AAP project provides an excellent baseline for this. Ideally, monitoring should be carried out **at regular intervals, e.g. as part of the national reporting obligations under the Habitats Directive**. Monitoring activities should especially **focus on species of international conservation concern,** such as those protected under the EU Habitats and Birds Directives. However, **species** that are characteristic of dry calcareous grasslands and **subject to regional conservation should also be considered**, since they can be well-suited indicators of the effects of habitat management, too. In order **to ensure data comparability** with other regions in Europe, **internationally established methodological standards should be used** wherever possible.

Figure 20: If dry calcareous grasslands are left unmanaged, shrubs such as the European Smoketree (*Cotinus coggygria*) can encroach on open grasslands, which in the long term deteriorates the habitat conditions for many specialised species. (Photo: Thomas Fartmann)

Figure 21: Shrub cutting with forest machinery can be used to restore dry grassland areas where possible. As the terrain in the Vértes Hills is often very steep, the removal of shrubs can often only be done by hand. To ensure the effectiveness of shrub removal, subsequent grazing should be carried out. (Photo: Felix Helbing)

Examples include pan-European programmes such as the European Butterfly Monitoring Scheme (eBMS) and the Pan-European Common Bird Monitoring Scheme (PECBMS), as well as national monitoring programmes such as the German Insect Monitoring Scheme, which is harmonised with international monitoring frameworks (Streitberger et al. 2024). As the conservation authorities in the Vértes Hills and beyond hardly have the necessary resources for biodiversity monitoring, **the involvement of volunteer conservationists for monitoring should be considered**. This could be done, for example, within the framework of the pan-European monitoring schemes mentioned above, which are also popular among Hungarian butterfly and bird enthusiasts.

3.6 Addressing perspectives and challenges for the implementation of habitat management

The implementability of habitat-management measures depends on a variety of socio-economic factors. First and foremost, it **requires cooperation between conservationists, foresters and farmers** as the key stakeholders in the Vértes Hills. In addition, it is crucial whether **regional conditions** permit the implementation of scientifically required measures and whether **sufficient resources** are available. As the dry calcareous grasslands in the Vértes Hills are protected under the EU Habitats Directive, there is a legal obligation to maintain them in a favourable conservation status. In the long term, this can only be achieved by establishing appropriate management measures, which should be accompanied by a **monitoring** of the effects of habitat management. Most of the land in the Natura 2000 site Vértes is state-owned and under the administration of the regional forestry department. This also applies to the majority of the dry calcareous grassland areas in the Vértes Hills, which were used as pastures in former times. Due to forestry legislation and for historical reasons (see Chapter 2.2), livestock grazing has been prohibited here. As a result, many of the dry grassland areas are not eligible for Hungarian agricultural funding programmes (MEPAR), which also include **agri-environmental schemes**. Only a few areas in the foothills of the Vértes Hills are designated for agricultural land use. Some of the dry grassland areas in the foothills are already being used in terms of biodiversity conservation. However, the **availability of funds for biodiversity-friendly farming is generally limited** and **compensations for practicing low-intensity agriculture are often low** (Batáry et al. 2015). An overview of possible funds for habitat management is given in Table 2.

Another challenge is that there are **only a few farmers left in the Vértes Hills**, who would be available for low-intensity livestock grazing or other measures of habitat management in the dry calcareous grasslands. In addition to a few small private farms and independent shepherds, the Pro Vértes Foundation holds the largest livestock populations in the region. As a non-profit organisation engaging in nature conservation, it is already running a large-scale grazing project with more than 700 Hungarian Grey Cattle, 200 Water Buffalo and several horses on an area of over 500 ha in the wet meadows of the Zámoly Basin (Csíkvarsai Meadows) in the southern foreground of the Vértes Hills. For the conservation of this area, agri-environmental funds from the EU were accessed by the Pro Vértes Foundation. In addition, the marketing of regional meat and sausage products also makes an important contribution to the economic viability of this conservation grazing project.

Figure 22: The implementation of habitat management depends essentially on the participation of local farmers and foresters. The availability of agri-environmental schemes is crucial to engage livestock holders, like this shepherd, in conservation-friendly grazing practices. (Photo: Thomas Fartmann)

Figure 23: The Pro Vértes Foundation runs a large-scale grazing project in the Csíkvarsai Meadows at the southern foreground of the Vértes Hills. The grazing of Hungarian Grey Cattle facilitates the biodiversity in this wetland area. (Photo: Thomas Fartmann)

Table 2: Overview of funding possibilities and exemplary projects on the conservation and management of grasslands in the Pannonian region

Fund type	Weblinks
(a) Funding possibilities	
Life Hungary	▪ https://lifepalyazatok.eu ▪ https://környezetvédelem.hu/kornyezetvedelmi-finanszirozasi-rendszerek-life
Hungarian agricultural subsidies	▪ https://mepar.mvh.allamkincstar.gov.hu ▪ https://környezetvédelem.hu/kornyezetvedelmi-finanszirozasi-rendszerek-tovabbi-hazai-palyazati-lehetosegek
EU-funded eco-schemes and environmental funds	▪ https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/eco-schemes_en ▪ https://környezetvédelem.hu/kornyezetvedelmi-finanszirozasi-rendszerek-unios-tamogatasi-alapok ▪ https://youreurope.europa.eu/business/finance-funding/getting-funding/access-finance/hu
(b) Exemplary projects in the Pannonian region	
Life	Project: Long-term conservation of Pannonian grasslands and related habitats through the implementation of Prioritized Action Framework (PAF) strategic measures ▪ https://www.grasslandlifeip.hu/en
Life	Project: Conservation of dry grasslands in Central Hungary ▪ https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE12-NAT-HU-001028/conservation-of-dry-grasslands-in-central-hungary
Life	Project: Pannonian steppes and dry grasslands in Austria ▪ https://www.bmluk.gv.at/themen/wasser/wasser-eu-international/eu-foerderprogramme/life-natur/life-projekte_abgeschl/pannonische-steppen.html
Pro Vértes Foundation	Project: Grazing in the Csíkvarsai Meadows ▪ https://provertes.hu/index.php/termeszetgazdalkodas/termeszetkimelo-gyepgazdalkodas/249-legeltetes-oshonos-allatokkal

From a nature conservation perspective, it would be highly desirable to **extend livestock grazing** in the Vértes Hills also to the dry calcareous grasslands on the slopes, possibly in collaboration with the **Pro Vértes Foundation**. One cost-effective possibility would be grazing the dry grassland slopes during a short period in early spring, when the grassland areas in the Zámoly Basin are still too wet for cattle grazing. As far as possible, **private livestock holders**, such as **independent shepherds** or **local horse owners**, should also be considered for the implementation of management measures like conservation grazing.

Under the current legal conditions, only **agro-forestry measures** such as shrub cutting or possibly also wood pastures could be implemented in the dry calcareous grassland areas under forestry administration. As in most parts of Europe, wood pastures are subject to severe legal restrictions in Hungary and thus they are restricted to forests with non-native tree species (Varga et al. 2020). Large-scale implementation of habitat management would, therefore, be possible only with **adjustments of the local forestry plans so that livestock grazing of dry calcareous grassland areas in the Vértes Hills would be officially allowed and agri-environmental measures can be applied** in these habitats. Since most of the land is not suitable for profitable forestry, this would have hardly any economic disadvantages. However, the forestry sector is also responsible for hunting and game management in the Vértes Hills, which enjoys a high status in the project region. Although, from an ecological point of view, the high game populations can also slow down succession of the dry calcareous grasslands, they also often cause conflicts in relation to agriculture, forestry as well as nature conservation in specific cases. Due to the large-scale occurrence of dry grassland areas in the Vértes Hills, most of which are publicly owned, **extensive grazing in the form of year-round pastures** would be a possible option for future habitat management. Although this seems a challenging task at present, there are already several projects in the Pannonian region, in which habitat management in dry grasslands has been successfully established in recent years. In addition to the aforementioned project by the Pro Vértes Foundation, this has mainly been achieved in the course of **EU Life projects** (Table 2). Such exemplary projects can provide important inspiration on how to address local challenges and implement measures for habitat management in the future.

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Front cover:
Sheep grazing in dry calcareous grasslands in the Natura 2000 site Vértes (Csákberény, Hungary) with characteristic species (from left to right): Three-toothed Orchid (*Anacamptis morio*), Orange-tipped Grasshopper (*Omocestus haemorrhoidalis*), European Roller (*Coracias garrulus*) and Safflower Skipper (*Pyrgus carthami*)

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