Dynamics of plant cover of meadow steppes after the cessation of traditional management in Opillia

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Abstract

Meadow steppes of Opillia (western edge of Podillia Upland, Western Ukraine) belong to xerothermic calcareous grasslands which are the most species-rich habitats in Europe. This paper contains results of a nine-year study (2010–2018 years) of plant species composition in ‘Ostrivets’ grassland after the cessation of traditional management (mowing). The patch had been burnt for at least five years running and then abandoned for more five years. The patch was chosen as a model grassland of abandoned meadow steppes. We examined plant species richness and composition on three sample plots of 5 x 5 m². In 2010, at the beginning of annual burning practice the plots harboured 114 species. One year after cessation of disturbance by fire (2014), species richness decreased to 108 species. In 2018, after five years of abandonment it reached 83 species. Abundance of the dominant species (Brachypodium pinnastrum) remained unchanged when the patch was under annual burning regime. After abandonment of the habitat Molinia arundinacea became the dominant species. Species composition experienced changes as well. Only 37.9% of species remained in the sample plots from 2010 till 2018. The proportion of meadow-steppe species halved, they were substituted by species of forests, forest edges and ruderal species. Percent of meadow species did not significantly change, however this group of species began to dominate within the community. The cover of woody vegetation reached 15–20% in 2018. Rubus caesius encroached on the grassland in 2014 and gained 20% of projective cover in 2018. Ten out of thirteen rare species disappeared from the habitat during the study period. ‘Ostrivets’ habitat requires urgent measures to be taken to restore and preserve meadow-steppe species composition. We suggest the following measures: elimination of trees and shrubs, regular moving and overseeding of extict species.

Keywords: meadow steppe; burning; abandonment; plant species richness; plant species composition; Opillia.

Introduction

Calcareous xerothermic grasslands, the most species rich habitats throughout Europe, are equally mostly threatened habitats (Poschlod & Wallis De Vries, 2002; Wallis De Vries et al., 2002; Butyane, et al., 2005). The majority of xerothermic calcareous grasslands originated as secondary vegetation after the clearing of forests, especially those on gentle slopes and hill plateaus. Extreme species richness has developed in sites with extreme conditions characterized by excess of light, soil moisture deficiency, low content of nutrients etc. (Gorbun, et al., 2020). Open short-grass vegetation in these habitats has been maintained firstly by wild herbivores that were later replaced by domestic grazing animals. Occasional fire and mowing complemented the impact of grazing. Such management lasted until the mid-XX century when agricultural intensification and afforestation began (Dzwonko & Loster, 1998). This land use resulted in fragmentation of natural landscape, reduction of habitat quality and decrease of species richness. As for xerothermic grasslands, the remaining ones were transformed into small and isolated patches, some of which were overgrazed, the others – abandoned. Decrease in species richness is a well-known consequence of cessation of traditional management in extremely species rich European xerothermic calcareous grasslands (Hansson & Fogelström, 2000; Poschlod et al., 2005; Provost et al., 2004; Pyšek et al., 2005; Römmermann et al., 2009; Stoate et al., 2009; When et al., 2017). Succession following abandonment of dry grasslands begins with increasing litter deposition, changes in soil nutrient availability, especially nitrogen, reduction of light availability, suppression of low-growing vegetation by tall expansive plants, encroachment of woody species etc. (Butyane, et al., 2005; Dostalek & Frantik, 2008). The small area of patches and isolation of habitats, as well as pesticide spillover from surrounding arable lands additionally accelerates deterioration of habitat quality (Krass et al., 2004; Zulka et al., 2014). Xerothermic grasslands in Opillia physiographic region (situated on the western edge of Podillia Upland, Western Ukraine) also exist in such unfavourable conditions. Opillia is highly transformed by humans and belongs to most ancient agricultural regions of Ukraine. Arable lands take up over 75 percent of its area. Consequently, remnants of natural and semi-natural vegetation are fragmented, isolated and altered by humans. Xerothermic calcareous grasslands are simultaneously among the most species-rich and transformed habitats in Opillia. Meadow steppes are extra-zonal vegetation here, as Opillia belongs to the deciduous forest zone (Rudenko, 2008). Meadow steppes have been established here at southern slopes of hills under grazing or mowing regime. Well preserved xerothermic grasslands currently occupy nearly 0.6% of the area; however, the habitat quality is rapidly deteriorating. In the last few years due to decrease of livestock number, plant species composition of the grasslands has been changing, they have been overgrown with thermophilous shrubs and trees. Gentle slopes and plateaus of hills are the most susceptible places for invasive species colonization.

Vegetation cover of meadow steppes of Opillia has been partially studied, the majority of papers focused on vegetation and rare species of xerothermic grasslands (Kukovitsia, 1976; Sheleg-Sosonko et al., 1981; Kukovitsia et al., 1994; Kukovitsia et al., 1998; Dmytrash-Vatseba, 2016, 2017; Zamoroka et al., 2018; Roleček et al., 2019). Transformation of plant cover of meadow steppes in Opillia caused by cessation of traditional land use remained unclear. ‘Ostrivets’ grassland was chosen for our study as it generally describes characteristic conditions of existence of meadow steppes in Opillia. The patch has been fragmented, the remaining part is up to 2 ha and is...
completely isolated. Agricultural lands surround the habitat on all sides. Plant cover of the grassland had been under different types of anthropogenic impact (mowing, early spring burning). Since disturbances had ceased, vegetation of the habitat began transforming. Besides its small area and isolation, at the beginning of our study the patch harboured a high species richness common to meadow steppes of Opillia. We have found a range of rare species of plants there.

In this paper we aimed to show changes in floristic composition and species abundance of the xerothermic grassland ‘Ostrivets’ at the beginning of annual burning, after several years of disturbance by fire and after five years of abandonment.

Material and Methods

‘Ostrivets’ xerothermic grassland situated near Medulka village of Halychy district of Ivano-Frankivsk region was chosen as the model patch of meadow steppes. Geographic coordinates were as follows: 49°09'58" N 24°50'00" E; the total area of the patch was 2 ha. The meadow steppe has formed at the flat top of the hill (330 m a.s.l.) with a karst sink hole in its central part, that is overgrown by shrubs and young trees. The patch of rectangular shape is surrounded on all sides by plowed fields that had not been cultivated for eighteen years. However, these lands have been sown with rapeseed and other crops for the last six years. ‘Ostrivets’ grassland was formerly used as a hayfield. However, in the early XXI century, the traditional management ceased and was replaced by annual early spring burning of dry grass. Such a disturbance lasted to 2013, and after renewal of cultivation of arable lands, the meadow steppe patch happened to be completely abandoned.

We studied species composition of vascular plants in three permanent sample plots, 5 x 5 m² in size in the years 2010 (vegetation was disturbed by fire), 2014 (one year after the cessation) and 2018 (five years after abandonment). Species records were made three times during a vegetation period: in March–April, in early June and in early August.

Projective cover in percent was estimated for each species. We used the Sørensen-Dice coefficient to calculate the similarity of species composition of the flora in sample plots between the years of study (KS) (Shmida, 1980).

\[ K_s = \frac{2N_{ab}}{N_a + N_b} \]

where \( N_a \) is the number of common species growing in sample plots in both years (\( a \) and \( b \)), \( N_a \) and \( N_b \) – are the general number of species per plot in a certain year.

Nomenclature of plant species follows Mosyakin & Fedoronchuk (2019). Systematics follow Mosyakin & Tyshchenko (2010) and Mosyakin (2013).

Results

General species number at three plots during the whole study period was 145. The highest species richness was found in 2010 (114 species of vascular plants in three plots), it slightly decreased when examined in 2014 (108 species) and was considerably lower in 2018 (83 species) (Table 1). Expressed in percentage terms, species richness per plot is equal to 78.6%, 74.5% and 57.2%, respectively. We have found significant changes in species composition during the study period. As many as 55 species (37.9%) remained in the grassland from 2010 till 2018, however most of them experienced alterations in projective cover.

Dry vegetation burning had stopped by 2013, thus a year later soil was covered with litter layer of 10–15 cm depth. Brachypodium pinnatum still dominated within the community, as it had been marked in 2010, with mean projective cover 60% in both years. 25 species disappeared from the community in the years 2010–2014. Most of them are low-growing species typical for xerothermic grasslands (meadow steppes) (Adonis vernalis, Astragalus danicus, Carex montana, Centaurea stricta, Chamamcytisiss pacczskii, Diaphus carthusianorum, Euphorbia angulata, Helianthemum chamacypsis, Lathyrus pannonicus, Pasalatia grandis, Thesium inophyllon, Veronica spicata etc.). Instead of this, twenty new species appeared in the patch in 2014. Many of them are mostly mesophilous meadow species (Anthoxanthum odorum, Galium mollugo, Geranium pratense, Holcus lanatus, Leucanthemum vulgare, Poa pratensis, P. trivialis), complemented with species of forest and forest edges (Anthriscus sylvestris, Chamaeion angustifolium, Convalaria majalis, Lathyrus sylvestris, Melandrium album, Pteridium aquilinum, Rubus caesius, Scrophularia nodosa).

Table 1

| Plant species                        | 2010 | 2014 | 2018 |
|--------------------------------------|------|------|------|
| Densiastricaeae                      | –    | 1.0  | 2.0  |
| Pteridium aquilinum (L.) Kuhn         | –    | –    | –    |
| Melandriumaceae                      | 1.0  | 2.0  | 2.0  |
| Lilium martagon L.                   | 0.5  | 0.2  | 0.1  |
| Orchidaceae                          |      |      |      |
| Dactylorhiza maculata (L.) Soó        | 0.1  | –    | –    |
| Gymmedenia campstris (L.) R. Br.      | 0.2  | 0.1  | 0.1  |
| Platyanthera bifida (L.) Rich.        |      |      |      |
| Iridaceae                            |      |      |      |
| Gladiolus imbricatus L.               | 2.0  | 5.0  | 1.0  |
| Allium olearcum L.                   | 0.1  | 0.1  | 0.1  |
| Agrostis rubra L.                     | 2.0  | 0.5  | 0.2  |
| Anthericum ramosum L.                 | 0.5  | 0.5  | 1.0  |
| Polygonatum odoratum (Mill) Drue      | 0.2  | 0.1  | 0.1  |
| Ruscaceae                            |      |      |      |
| Consoliria majalis L.                 |      | 1.5  | 2.0  |
| Luzula campestris (L.) DC.            | 1.0  | 1.0  | 1.0  |
| Carex montana L.                     | 5.0  | –    | –    |
| C. micheli Host                      | 0.1  | 0.1  | 0.1  |
| Poaceae                              |      |      |      |
| Agrisopsis capillaris L.              | 0.5  | 0.2  | –    |
| Anthoxanthum odoratum L.              | –    | 0.2  | –    |
| Arrhenatherum elatius (L.) J. Presl & C. Presl | 5.0  | 2.0  | 1.0  |
| Brachypodium pinnatum (L.) Beav.      | 60.0 | 60.0 | 10.0 |
| Briza media L.                        | 1.0  | 2.0  | 5.0  |
| Brachypodium lanulatum (Leyss.) Holub | 5.0  | 5.0  | 10.0 |
| Calamagrostis epigeios (L.) Roth      | 1.0  | 1.0  | 2.0  |
| Dactylis glomerata L.                 | 0.2  | 0.2  | 0.5  |
| Elytrigia intermedia (Host) Nevski    | 0.5  | 1.0  | 0.0  |
| Festuca valessiana Gaudin             | 10.0 | –    | 0.5  |
| Holcus lanatus L.                     | –    | 0.5  | 0.5  |
| Molinia arundinacea Schnurk           | 10.0 | 20.0 | 85.0 |
| Poa neemoralis L.                     | 0.1  | 1.0  | 1.0  |
| P. pratensis L.                       | –    | 0.5  | 0.5  |
| P. trivialis L.                       | –    | 10.0 | –    |
| Trisetum flavescens (L.) P. Beauv.    | 0.1  | 0.2  | –    |
| Ranunculaceae                         |      |      |      |
| Adonis vernalis L.                    | 0.2  | –    | –    |
| Anemone coccinea L.                   | 0.5  | 0.1  | 0.1  |
| A. sylvestris L.                      | 2.0  | 0.5  | 0.5  |
| Pulsatilla grandis Wender             | 0.5  | –    | –    |
| Ranunculus acris L.                   | 0.1  | 0.1  | 0.1  |
| R. зукадовичii Pacz.                  | 0.5  | –    | –    |
| Trachymetrum minus L.                 | 0.5  | 0.5  | –    |
| Fabaceae                              |      |      |      |
| Astragalus danicus Retz.              | 0.5  | –    | –    |
| A. glaucaefolius L.                   | –    | 0.5  | 1.0  |
| Chamamcytisiss blockanum (Pavč) Klasiková | 5.0  | 2.0  | –    |
| Ch. pacczskii (V. Krecz.) Klasiková    | 0.2  | –    | –    |
| Genista tinctoria L.                  | 5.0  | 2.0  | –    |
| Lathyrus nigrier (L.) Bernh.          | 0.5  | 0.5  | 0.5  |
| L. pannonicus (Jaq.) Gunko            | 0.1  | –    | –    |
| L. sylvestris L.                      | –    | 0.5  | –    |
| Lotus corniculatus L. s.l.            | 2.0  | 2.0  | 0.5  |
| Medicago falcata L. s.l.              | 5.0  | 5.0  | 2.0  |
| Securigera varia (L.) Lassen          | 12.0 | 15.0 | 5.0  |
| T. montanum L.                        | 2.0  | 2.0  | 1.5  |
| T. pannonicus Jaq.                    | 0.5  | 0.5  | 0.2  |
| Vicia sepsim L.                       | –    | 0.1  | –    |
| V. temperfolia Roth                   | 5.0  | 2.0  | 1.0  |
In 2018 the projective cover of Brachypodium pinnatum decreased to 10%, so the dominant species has changed. Molinia arundinacea has formed a dense stand of 2 m height with projective cover 85%. Depth of litter cover above soil reached 30 cm. The habitat lost 26 more species in the period of 2014–2018; many of them are typical for meadow-steppe vegetation (Anemone sylvestris, Asperula cynanchica, Bupleurum falcatum, Carex mackiei, Chamaeactys bocki, Elytrigia intermedia, Filipendula vulgaris, Genista tinctoria, Inula hirta, Tescinarion chamaejdy, Thalictrum minus etc.). Nine new species were found there instead.

We represented shifts of species composition of flora during the study period in a form of pairwise Sorensen-Dice’s similarity coefficient (Table 2).

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### Table 2

Similarity matrix of species composition at studied plots for the period of observation

| Years | 2010 | 2014 | 2018 |
|-------|------|------|------|
| 2010  | –    | 85   | 55   |
| 2014  | 0.77 | –    | 80   |
| 2018  | 0.56 | 0.84 | –    |

Note: values above the diagonal are number of species common to both years; values below the diagonal are pairwise Sorensen-Dice’s similarity coefficient.

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### Dissimilarity of floras composition

Dissimilarity of floras composition between the years of first and second, as well as of second and third recording was slightly fewer than half of the general species number (41.4–44.2%). Species composition shift for the whole study period (2010–2018 years) was significant...
‘Ostrivets’ grassland has been rapidly overgrown with trees and shrubs during the study period. In 2010 only two young trees grew within the patch (Populus tremula and Quercus robur), forming general projective cover of 0.6%. In 2014 there appeared two new species – Tilia cordata and Carpinus betulus, and their total projective cover increased to 6%. Additionally, Rubus caesius appeared within the community and got to the overgrown stage (projective cover – 5%). In 2018 six new species of shrubs and trees entered the vegetation: Betula pendula, Corylus avellana, Malus sylvestris, Prunus spinosa, Salix caprea, Viburnum opulus. Their general projective cover continued to increase (15–20%) as well as the cover of Rubus caesius (up to 20%).

The relation between eco-coenotical groups of species has been also considerably changing during the study period (Fig. 1).

**Discussion**

Changes in species composition of ‘Ostrivets’ xerothermic grassland are generated by two consistent events: annual burning and abandonment. Cessation of any disturbance initiated succession processes while frequent fire had defined their direction. Usually xerothermic grasslands after abandonment experience increasing dominance of Brachypodium pinnatum (Bobbinck & Willems, 1987, 1991; Kahmen et al., 2002; Köhler et al., 2005), sometimes of *Arrhenatherum elatius* (Dostálek & Frankit, 2008) and other competitively strong species (Garnath, 2007; Hille & Goldammer, 2007; Marozas et al., 2007; Hegedušová & Senko, 2011; Deák et al., 2014). *Brachypodium pinnatum* can gain over 80% of vegetation cover and induce a decrease in species number to less than 50% of the original number (Bobbinck & Willems, 1987). Increased abundance of this species may occur after abandonment of traditional management, as well as under different management practices (Zimmermann 1979; Wilmanns & Kratochvíl, 1983; Bobbinck & Willems, 1987). Therefore, much research is focused on developing methods to control density of *Brachypodium pinnatum* in grasslands (Bobbinck et al., 1988; Bobbinck & Willems, 1991; Schlapefl 1997; Farmer & Baxter, 1998; Hurst, 1999; Redhead et al., 2019).

Among meadow steppes of Podillia *Brachypodium pinnatum* grasslands are one of the most species-rich habitats (Roleček et al., 2019). In other regions *Brachypodium pinnatum* dominated grasslands also harbour high species richness (Illyés et al., 2009; Roleček et al., 2014). In dry grasslands of Opillia the tor-grass usually has projective cover 50–70% forming pure stands only on tops of hills with lack of disturbance. In our study the primary cover of the dominant species was 60% and it remained unchanged after at least five years of annual burning. However, during the next five years of abandonment *Brachypodium pinnatum* was replaced by *Molinia arundinacea*.

Purple moor-grass is supposed to invade different habitat types after frequent fires (Bensettiti et al., 2005; Jacquemyn et al., 2005; Calaciuca & Spinelli, 2008). Also some papers reported increased dominance of other tall competitive grasses such as *Brachypodium pinnatum* (Kahmen et al., 2002; Köhler et al., 2005), *Calamagrostis epigeios* (Hille & Goldammer, 2007; Marozas et al., 2007) or *Phragmites australis* (Deák et al., 2014).

In our study abundance of *Brachypodium pinnatum* between the years 2010 and 2014 remained unchanged, but there was a significant decrease in it after five years of abandonment. Abundance of *Molinia arundinacea* doubled in 2014 against 2010 (10% and 20%, respectively) and increased up to 85% in 2018 after abandonment. Burning and abandonment did not significantly foster or delay the expansion of other competitors (projective cover of *Arrhenatherum elatius* decreased from 5% in 2010 to 2% in 2014, but then increased to 10% in 2018, whereas the cover of *Calamagrostis epigeios* increased from 1% to 10% after annual burning, however it almost reached the initial level after cessation of disturbance). Frequent burning allowed the encroachment of such species as *Rubus caesius*, *R. idaeus* and *Pteridium aquilinum*. Projective cover of the first species reached 20% in 2018 and counting.

Fire as the method of supporting species richness in European grasslands is highly controversial. On the one hand, burning is the easiest way to eliminate accumulated plant litter in abandoned grasslands, to suppress shrubs and pioneer trees encroachment and, thus, to sustain appropriate habitat conditions for existence of xerothermic species, including a great variety of rare species. Many plant species respond well to quick fire, exhibit no damage after burning of their above-ground parts or even benefit from fire (Deák et al., 2014; Feurdean, 2018). Recent research has
showed that fire had been much more important to developing and main-
taining of grassland vegetation in Europe than had been thought before 
(Valkó et al., 2016; Pereira et al., 2017; Feurdean, 2018).

However, a lot of research has shown negative impacts of fire on 
vegetation in European grasslands due to increased germination of invasive 
species, dominance of Brachypodium pinnatum and decreased species 
richness (Kühn et al., 2002; Moog et al., 2002; Kohler et al., 2005; Pereira et al., 2017).

‘Ostrivets’ grassland had been under fire regime for no less than five 
years running. We examined floristic composition after a year of cessation of 
annual burning and compared it to the species composition in 2010 (during 
animal burning). While the general species number did not significantly 
decrease (6 species), species composition considerably changed. Species 
characteristic for meadow steppes (e.g. Adonis vernalis, Pulsatilla grandis, 
Thesium linophyllum, Lathyrus pannonicus etc.) were substituted for species 
common for meadows, forests and shrub edges. Ruderal species also were 
noticed in the habitat. Our results show that at the beginning of disturbance 
by annual fire, burning was not detrimental for plant cover of ‘Ostrivets’ 
grassland, while five or more years of annual burning were too much and 
caus ed a degradation of the habitat.

The next five years of abandonment, instead of regeneration, brought 
further deterioration of habitat quality. Molinia arundinacea became domi-
nant, created a thick litter layer, the habitat was gradually overtaken by 
woody species, European dewberry and others. Altogether 61 species disap-
peared from the habitat. Abundance of forest species, species of forest edges 
and ruderals considerably increased.

‘Ostrivets’ grassland harboured populations of thirteen rare species. 
In 2010 eleven species were found listed in the Red Data Book of Ukraine 
(Dúdik, 2009) (Adonis vernalis, Anemone narcissiflora, Carlina ciriataeides, 
Chamaecytisus blockianus, Ch. paccozkii, Dactylorhiza maculata, Gladiolus imbricatus, Gymnadenia conopsea, Lilium martagon, Platandertha bifolia, 
Pulsatilla grandis) and three species in international conservation lists (1 – in 
Annex 1 of Bern Convention (1979) – Pulsatilla grandis; 1 – in Revised 
Annex 1 of Resolution 6 of the Bern Convention (2011) – Adenophora 
ililifolia; 3 – in Annex IV of Council Directive 92/43/EEC (1992) – Pulsatilla 
grandis, Adenophora lilifolia, Serratula lycopsis.). In 2014 we found no 
sign of Adonis vernalis, Chamaecytisus paccozkii, Dactylorhiza maculata, 
Pulsatilla grandis and Serratula lycopsis. In 2018 only three rare species 
grew within the habitat (Adenophora lilifolia, Gladiolus imbricatus and 
Lilium martagon).

‘Ostrivets’ grassland is a valuable patch of xerothermic grasslands, which 
are highly endangered throughout the Europe (Calaciuara & Spinnelli, 
2008). It harboured both high species richness and a range of rare species. 
However, the habitat currently needs management measures to suppress its 
overgrowth and degradation. The first step is removing woody vegetation. 
Taking into consideration the disposition of the patch (far from adjacent 
habitats and surrounded by agricultural lands), the most appropriate man-
agement practice would be mowing. It might be combined with burning, 
however at most once in three-five years (Deák et al., 2014). After these 
measures are taken, restoration of origin species composition will require 
overseeding of the lost species because of the impermanent character of the 
seed bank of calcareous grasslands (Butuye et al., 2005).

Conclusion

The traditionally mowed grassland ‘Ostrivets’ became a refugium for 
 xerothermic flora with high species richness. The species composition was 
complemented by meadow species, and in a minor way – by species of 
forests and forest edges. After the cessation of traditional management, the 
original habitat conditions had been maintained by early spring annual 
burning for a few years without any significant deterioration of the habitat 
quality. However, continuation of burning resulted in decrease of general 
species richness, encroachment of shrubs, trees and ruderals, increase of 
proportions of species of forests and forest edges, loss of populations of 
rare species. The next five years of abandonment completely transformed 
the habitat. The dominant species (Brachypodium pinnatum) was substi-
tuted by Molinia arundinacea. The projective cover of woody vegetation 
reached 20% and the same area was under Rubus caesius. Only three 
(Adenophora lilifolia, Gladiolus imbricatus and Lilium martagon) of 

thirteen rare species remained in sample plots after abandonment. Without 
some urgent measures, such as tree and shrub removal and implementa-
tion of traditional management ‘Ostrivets’ grassland will soon be com-
pletely overgrown.

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