SAFEGUARD

Recommendations on how to implement effective interventions to enhance pollinators in Natura 2000 areas and in public space

Deliverable D4.2

16th February 2024

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Safeguard
Safeguarding European wild pollinators

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003476.

Prepared under contract from the European Commission

Grant agreement No. 101003476.
EU Horizon 2020 Research and Innovation action

Project acronym	Safeguard
Project full title	Safeguarding European wild pollinators
Start of the project	September 2021
Duration	48 months
Project coordinator	Ingolf Steffan-Dewenter Julius-Maximilians-Universität Würzburg https://www.safeguard.biozentrum.uni-wuerzburg.de/
Deliverable title	Recommendations on how to implement effective interventions to enhance pollinators in Natura 2000 areas and in public space
Deliverable n°	D4.2
Nature of the deliverable	Report
Dissemination level	Public
WP responsible	WP4
Lead beneficiary	HUN-REN Centre for Ecological Research
Citation	Süle, G., Szigeti, V. & Báldi, A. (2024). *Recommendations on how to implement effective interventions to enhance pollinators in Natura 2000 areas and in public space*. Deliverable D4.2 EU Horizon 2020 Safeguard Project, Grant agreement No 101003476.
Due date of deliverable	Month 30
Actual submission date	Month 30

Deliverable status:

Version	Status	Date	Author(s)	Reviewer(s)
1.0	Draft	05 February 2024	HUN-REN Centre for Ecological Research	Gabriella Süle, Viktor Szigeti, András Báldi
1.1	Draft	08 February 2024	University of Würzburg, Wageningen University	Ingolf Steffan-Dewenter, David Kleijn
1.2	Draft	16 February 2024	HUN-REN Centre for Ecological Research	Gabriella Süle, Viktor Szigeti, András Báldi

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Summary

Pollinators, as important ecosystem service providers, have become a flagship of nature conservation and are supported by providing floral sources and nesting sites. In agricultural systems, multitudes of studies have already addressed the ecological effectiveness of pollinator-promoting measures. However, there are knowledge gaps and also several opportunities to step forward, because we need to move out of the farmland – where the vast majority of evidence comes from – and safeguard pollinators in cities and protected habitats too. Nowadays, studies on pollinator-promoting interventions in urban and protected areas are increasing. However, meta-analysis or continent-level re-analytical data-synthesis is lacking, while local authorities and citizens still need detailed information and guidelines. We aimed to synthesize the impact and effectiveness of pollinator-promoting interventions on the pollinators, floral resources, and vegetation in urban and protected (incl. Natura 2000) areas within Europe. We conducted a re-analytical data-synthesis by re-analysing primary data from multiple datasets. We were interested in the success of the interventions addressing pollinators by comparing management targeted to promote pollinators (treatment) and management not addressing pollinators (control) using 28 urban and 32 protected habitat-focused datasets. In addition, we investigated in depth the impact of pollinator-promoting interventions (extensive mowing and flower sowing) on pollinators and wildflowers through three case studies from Hungary. We aimed to identify the shortcomings and specificities of pollinator-promoting interventions by these case studies from an Eastern European country and to make suggestions for the enhancement of such urban pollinator-promoting projects and monitoring studies.

The studied pollinator-promoting interventions had a generally positive effect based on the gathered datasets but vary by the studied parameters, pollinator guilds, and probably by the influence of the year-to-year and regional conditions. However, we identified several knowledge gaps, which should be addressed by future research to design more effective interventions. A major bias is that just a few types of intervention were studied by the gathered datasets. For example, nesting sites such as bee hotels, nest boxes, and bare ground surfaces are hardly studied in urban areas. Besides nesting resources, habitat quality can be improved by food resources, where sowing or planting herbaceous plant species are widely used methods. However, the diversification of the vegetation structure through planting shrubs and trees and building green roofs are also rarely studied. In addition, pollinator guilds are also not equally investigated. Non-syrphid flies and flower-visiting beetles are rarely studied, while they may deserve similar attention. In protected areas, extensive mowing or grazing and abandonment are widely used methods, but flower sowing and mulching were hardly considered, while the impact of prescribed burning is almost unknown in Europe. In addition, vegetation types are also not equally represented because forests were rarely surveyed.

Unfortunately, compared to some Western European examples, in Eastern European countries, the urban pollinator-promoting interventions are still in their early stages. The lack of monitoring and the potential management inaccuracies of pollinator-promoting interventions are concerning issues and decreasing the potential efficiency of these interventions. Our case studies revealed different types of pollinator-promoting interventions (i.e. extensive mowing and flower sowing), as complementing each other side by side in two cities in Hungary. However, a mosaic mowing system alone would be a suitable solution to provide continuous food resources during the whole season establishing more resilient vegetation. We also recommend using only native seed mixtures, containing a higher proportion of perennial species, facilitating the long-term establishment of sown areas and reducing management costs. Besides ecological impacts, societal adoption of interventions should also be taken into account. For the Hungarian urban pollinator-promoting interventions, we started to establish long-term monitoring and feedback systems also for the local authorities. Based on our feedback, the interventions have already been adjusted and improved.

1. Introduction

Pollinators have a fundamental role in the viability and functioning of terrestrial ecosystems by facilitating plant reproduction (IPBES 2016), including the maintenance of diverse agriculture (Kleijn et al. 2015; Vanbergen et al. 2020). However, the diversity of pollinators is declining worldwide due to climate change, pesticides, diseases, and land use changes (Potts et al. 2010; Goulson et al. 2015; Ollerton 2017). This entails strong threats to human food security by losing pollination of crop species (Corbet et al. 1991; Vanbergen et al. 2020). Pollinators, as important ecosystem service providers, have become a flagship of nature conservation in the last decades (Kovács-Hostyánszki et al. 2017). Pollinating insects can be supported by actions providing floral and larval food sources, as well as nesting and overwintering sites (Kovács-Hostyánszki et al. 2017; Mottershead and Underwood 2020). In farmlands, approaches of ecological intensification try to support sustainable agricultural production by the function of nature (i.e. boosting ecosystem services), while minimising the long-term loss of economic income and unfavourable effects on the environment (Bommarco et al. 2013). For example, agri-environment schemes supporting farmers are becoming common in the EU and worldwide trying to help transition from intensive agriculture and halt the pollination crisis (Gohin and Zheng 2020). In agricultural systems, a multitude of studies, including meta-analyses and reviews, have already addressed the ecological effectiveness of these measures (e.g. flower strips (Albrecht et al. 2020), field margins (Marshall 2005), set-aside (Kovács-Hostyánszki et al. 2021), and organic farming (Carrié et al. 2018)) on pollinators (Kovács-Hostyánszki et al. 2017). However, there are knowledge gaps and also several opportunities to step forward with these pollinator-promoting interventions. For instance, we need to move out of the farmland and safeguard pollinators within their all potential habitats, even in cities and (semi-)natural (e.g. Natura 2000 and protected) habitats.

In the case of habitats within urban settlements, the main research focus has been the negative effects of urbanisation on pollinators, as detrimental land use changes causing significant habitat loss (Persson et al. 2020; Prendergast et al. 2022; Liang et al. 2023). However, some urban habitats could promote pollinators. This topic has only been started to investigate 1–2 decades ago (Valtonen et al. 2006; Blackmore and Goulson 2014; Lerman et al. 2018; Norton et al. 2019; Baldock 2020; Phillips et al. 2020). As an urban pollinator-promoting intervention, short-term abandonment or reduced mowing frequency could be an easy-to-implement and cost-effective option (Garbuzov et al. 2015; O'Sullivan et al. 2017). These measures naturally increase the floral food resources compared to conventional, intensive, and regular mowing on herbaceous green infrastructures such as parks and road verges (Wastian et al. 2016; Del Toro and Ribbons 2020). Flower strips, an approach often applied in farmlands (Albrecht et al. 2020; Báldi et al. 2022), are also increasingly used in public spaces as smaller patches sown by different flowering seed mixtures (Blackmore and Goulson 2014; Norton et al. 2019; Dietzel et al. 2023; Süle et al. 2023a). Beyond floral resources for pollinators, these colourful patches can also boost the larvae and overwintering phase, and provide multiple ecosystem services, like buffering the microclimatic conditions, retaining water, and offering aesthetic value for citizens as co-benefits (Noordijk et al. 2009; Southon et al. 2017; Unterweger et al. 2018; Lange-Kabitz et al. 2021; Wintergerst et al. 2021). Provision of above-ground nesting sites (e.g. 'bee hotels') and bare ground surfaces could be an effective solution to increase sites available for offspring of cavity- and ground-nesting (bee) species (Potts et al. 2005; Fortel et al. 2016; Baldock 2020). Furthermore, similarly to the agricultural systems, the decreased use of herbicide, insecticide, and fertilizer can also reduce the harmful effects on pollinators and whole ecosystems in cities (Winqvist et al. 2012; Muratet and Fontaine 2015). All of these pollinator-promoting approaches could be applied not only in public spaces but also in small private gardens, allotments, green roofs, and balconies (Shwartz et al. 2014; Foster et al. 2017; Baldock et al. 2019).

In contrast, in Natura 2000 and protected areas, we know little about the ecological processes of management effects, (based on our opinion) due to the strong trust or belief that the management of protected areas is appropriate in most of the cases (Leverington et al.

2010). However, this is rarely evidenced by scientific research, while the importance of these areas for biodiversity and conservation is outstanding (Gaston et al. 2008; Underwood et al. 2017). Unfortunately, pollinators in general are relatively rarely targeted directly in Natura 2000 and protected areas management plans (ECA 2020). Some types of habitat management can benefit them, e.g. buffer strips left for birds (Kőrösi et al. 2014; Westbury et al. 2017). In addition, the habitat and vegetation types are highly varying within protected areas (Gaston et al. 2008), thus the type of pollinator-promoting interventions can be much more diverse in comparison to farmlands or urban areas. In grasslands, one of the most frequently used interventions to help pollinators is to reduce the mowing frequency (Kőrösi et al. 2014), resulting in higher and more structured vegetation and greater food resources (Valtonen et al. 2006). Grassland can be also maintained by grazing, where reducing grazing intensity can also provide food and nesting habitats for pollinators (Sárospataki et al. 2009; Hopfenmüller et al. 2020). Decreasing management intensity could generally cause positive effects (Kovács-Hostyánszki et al. 2017), and abandonment can be a good pollinator-promoting intervention, but not for all vegetation types and all regions (Walcher et al. 2019). In most cases, low-intensity mowing or grazing may be necessary to avoid vegetation degradation and late succession processes e.g. scrub encroachment (Ernst et al. 2017; Mora et al. 2021). Restoration with natural processes (e.g. early succession) or with active supplementation (e.g. overseeding with native herbaceous seed mixtures) can result in higher habitat quality for pollinators (Eckerter et al. 2022). There can be, however, complex functional relationships between landscape and local effects, which highlight the need for careful design of management (Pellaton et al. 2023). In the case of woodland habitats, some novel forest management approaches, e.g. gap-cutting treatment (Samu et al. 2023), coppicing (Benes et al. 2006), continuous cover forestry (Duflot et al. 2022), could be promising as pollinator-promoting intervention, as they establish favourable microclimatic conditions, promote the development of flowering plants providing food for pollinators (Eckerter et al. 2021; Kozel et al. 2021).

Nowadays, the citizen- and expert-based studies on pollinator-promoting interventions in urban and protected areas are steadily increasing (Griffiths-Lee et al. 2022; Rada et al. 2023) including also a few reviews (O'Sullivan et al. 2017; Baldock 2020; Phillips et al. 2020; Braman and Griffin 2022; Glenny et al. 2022). However, based on a thorough search to our knowledge, meta-analysis or continent-level re-analytical data-synthesis (i.e. analysis of primary data) is lacking, except for the management actions on pollinators within public lands in the USA by Glenny et al. (2022). Local authorities and citizens still need detailed information and guidelines to enhance the positive effects of pollinator promotion (Wilk et al. 2019; Tremblay and Underwood 2023). Therefore, synthesizing scientific results on the role of land management, conservation initiatives, and citizens' investigations for pollinators could help to safeguard and even deeply understand the plant-pollinator systems. Halting the decline of pollinating insects and maintaining greener cities are important goals of the European Union (Council of the EU 2023), essentially needing comprehensive, data-driven, and continent-level studies on urban and Natura 2000 pollinator-promoting interventions.

To address these knowledge gaps, we aimed to synthesize the impact and effectiveness of pollinator-promoting interventions on the vegetation, floral resources, and pollinators in urban and protected areas within Europe. We perform re-analytical data-synthesis of primary data from existing datasets across Europe. We were interested in the success of the interventions addressing pollinators by changing management from conventional to conservation-driven in urban and protected habitats. We were keen to explore what previous studies had focused on and what knowledge gaps could be identified. We compared the vegetation height and cover as well the abundance and species richness of floral resources and pollinator guilds between management interventions trying to promote pollinators (treatment) and management not addressing pollinators (control) using a total of 60 (28 urban and 32 protected habitat-focused) collected case study datasets.

In addition, we witnessed a 'Western' dominance in urban pollinator-promoting interventions. In several cities in the USA and Western Europe, these interventions have been widely introduced, and initiatives (e.g. 'No Mow May', 'All-Ireland Pollinator Plan', 'UK National

Pollinator Strategy') are helping cities by management guidelines, involving inhabitants in citizen science projects, and revealing the effectiveness by monitoring programmes (DEFRA 2014; Domroese and Johnson 2017; Wilk et al. 2019; Del Toro and Ribbons 2020; Mody et al. 2020; NBDC 2020). In contrast, in Eastern Europe (i.e. in most of the post-Soviet countries), the proportion of urban green spaces decreased until recently (Kabisch and Haase 2013; Kronenberg 2015), while this trend seems to be slowly reversing (Pauleit et al. 2019; Gavrilidis et al. 2020). Pollinator-promoting projects and monitoring studies have been started only in the last few years with a great variation among these countries (Skórka et al. 2013; Dylewski et al. 2019, 2020; Báthoryné et al. 2021), where biodiversity may be generally higher than in most parts of Western Europe (Batáry et al. 2010; Báldi et al. 2013; Kovács-Hostyánszki et al. 2016; Török et al. 2020). However, culturally negative attitudes can be observed towards such projects (Kronenberg 2015) compared to Western Europe (Hoyle et al. 2017; Southon et al. 2017). In the Eastern European region, detailed knowledge of the effectiveness of such pollinator promotion projects is still lacking. There are several studies about the effect of urbanisation on pollinators (e.g. Prague, Czech Republic; Konvicka and Kadlec 2011 and Poznan, Poland; Banaszak-Cibicka and Żmihorski 2020; Dylewski et al. 2020), but only a few took the impact of the local management of public green spaces into account (e.g. Poznan, Poland; Dylewski et al. 2019; Pardubice, Czech Republic; Horák et al. 2022, and Prague, Czech Republic; Rada et al. 2023). Hence, we investigate the impact of pollinator-promoting interventions (extensive mowing and flower sowing) on pollinators and wildflowers through three case studies from two Eastern European cities (Budapest and Veszprém in Hungary; Süle et al. (2023a)). We used an experimental approach, where we sampled pairs of urban green areas. One half of the site pairs were treatment sites (extensively mown or sown areas), while the other half of the pairs were control sites (conventionally managed areas with intensive mowing). We were interested in the (i) differences between the treatment and control sites in vegetation height and cover, the abundance and morphogroup richness of flowers and pollinators; (ii) temporal changes in the vegetation, pollinators, and flowers within two seasons; (iii) compositional differences in communities of pollinator guilds between the treatment and control sites during season. We aimed to identify the shortcomings and specificities of pollinator-promoting interventions by example studies from an Eastern European country (Hungary) and to make suggestions for the enhancement of such urban pollinator-promoting projects and monitoring studies (Süle et al. 2023a).

In the case of the Methods and Results parts of this report, we divided those into two main parts: 1) Re-analytical data-syntheses on 1a) urban and 1b) protected areas, as well 2) Urban case studies in Hungary. While in the Discussion, we present joint recommendations based on the data-synthesis and case studies, for comprehensibility.

2. Re-analytical data-syntheses on pollinator-promoting interventions

2.1. Methods of the re-analytical data-synthesis

2.1.1. Why a re-analytical data-synthesis, not a meta-analysis?

We targeted to perform re-analytical data-synthesis by re-analysing primary data on pollinator-promoting interventions. Compared to classical meta-analysis, re-analytical data-synthesis offers opportunities for a deeper understanding by more robust models including site-level factors and case study-level variances. Re-analytical data-synthesis is an effective approach, especially when the available datasets from case studies are still limited (Gurevitch et al. 2018). Re-analysing previous datasets is also beneficial to avoid killing more insects by destructive sampling techniques, which is an increasingly pressing ethical issue these days (Lövei and Ferrante 2024). By the reuse of existing data, we also perform a low-carbon scientific approach (Ben-Ari 2023). Gathering datasets for re-analytical data-synthesis is a more labour-intensive process than extracting data from publications for a meta-analysis. While a meta-analysis can only be investigated on the basis of a relatively higher number of publications, any study based on re-analytical data-synthesis can even apply to fewer datasets, at smaller but finer scale systems. We are aware that, in addition to the collected datasets, there may be many further datasets on this topic within and beyond Europe. The data-gathering process may have been influenced by several factors, e.g. mistrust against our unknown research institute from Eastern Europe, data owners having no time to do this extra task besides their high workload and receiving many data requests with a few successful publication outcomes (Renzl 2008; Stieglitz et al. 2020). In the case of re-analytical data-synthesis, a very high number of authors need to be consulted several times during the data-gathering process, and after involving them in the manuscript writing.

2.1.2. Data queries

To investigate re-analytical data-synthesis on pollinator-promoting interventions in urban and protected areas, we aimed to gather and integrate all the available datasets on these topics within Europe. To find studies and authors who did any investigations on the effects of habitat management on pollinators in urban and protected areas, first, we searched for publications in the Web of Science (WoS; **https://www.webofscience.com/**) database. We compiled two separate queries upon three groups of search terms for both topics, where the first two groups were the same:
(i) habitat management: ‘conservation management’, ‘conservation measure’, ‘cut*’, ‘cutting’, ‘establish*’, ‘floral addition*’, ‘flower addition*’, ‘graze*’, ‘grazing’, ‘habitat restoration’, ‘maintain*’, ‘management’, ‘mow*’, ‘mowing’, ‘planting*’, ‘pollinator conservation’, ‘pollinator friendly’, ‘promote*’, ‘restorat*’, ‘seeding*’, ‘shear*’, ‘shearing’, ‘sow*’;
(ii) pollinators: ‘bee flies’, ‘bee fly’, ‘bees’, ‘butterfl*’, ‘flower visitor*’, ‘hover flies’, ‘hoverfl*’, ‘hoverfly’, ‘hymenoptera*’, ‘lepidoptera*’, ‘moth*’, ‘pollinat*’, ‘syrphid*’, ‘wasp*’;

- for urban topic: (iii) urban habitats: ‘bee forage*’, ‘bee pasture*’, ‘green space*’, ‘greenspace*’, ‘lawn*’, ‘park*’, ‘public space’, ‘road verge*’, ‘roadside verge*’, ‘urban’, ‘urban space*’.
- for protected topic: (iii) protected habitats: ‘areas of conservation’, ‘conservation area’, ‘habitat conservation’, ‘habitats directive’, ‘landscape area’, ‘N2000’, ‘natural habitats’, ‘natura 2000’, ‘natura2000’, ‘national park’, ‘nature reserve’, ‘protected area*’, ‘protection area*’.

We used the ‘AND’ operator between groups and the ‘OR’ operator between keywords within groups; ‘*’ denotes wildcards. By the ‘NOT’ operator, we excluded ‘mother*’; and ‘parking’, ‘national park*’ from the second and third keyword’ groups, respectively, to avoid a large amount of irrelevant publications. These searches at WoS on 8 March 2023 by the ‘TS=topic’ tag (i.e. Title, Abstract, Author Keywords, and Keywords Plus) yielded 1,644 and 1,222 publications for urban and protected queries, respectively.

2.1.3. Data selection

The gathered publications were selected by the title, abstract, and full text according to the following (inclusion) criteria: study sampled (1) abundances and species richness of pollinators; (2) within urban or protected areas; (3) in Europe; (4) with different management intensity between at least three treatment (pollinator-promoting management) and three control (conventional management/not beneficial for pollinators) site groups. We excluded papers that studied non-pollinating insects (e.g. investigations on the larvae phase of butterflies and hoverflies). For ‘protected topic’, we included datasets beyond Natura 2000 areas such as other types of protected sites (i.e. IUCN Protected Area Management Categories (Dudley 2008) and Special Area of Conservation (European Commission 1992)). To reach all the potential authors with suitable datasets, we contacted all the corresponding authors of the included papers. Furthermore, to reach non-published, grey databases, we contacted colleagues working on this topic, and also the network of researchers within the

Safeguard project. We sent out >150 data-gathering emails to the potential data owners in several, repeated rounds between 01.10.2022. – 01.05.2023. We offered authors sharing their data and participating in manuscript writing a maximum of two co-authorships. We also received recommendations about other suitable datasets held by their colleagues. Finally, we gathered in total 60 (28 urban and 32 protected) datasets (including ongoing case studies of Safeguard partners) fitting our scopes.

2.1.4. Attributes of the datasets

In terms of analysis and results of this report, we focus primarily on urban datasets due to the urban topic being under the manuscript phase, while the datasets of the protected topic are in a previous phase, here, we provide some preliminary results.

We requested information on the study design (e.g. treatment types, habitat types), and data on the vegetation height and cover, abundance and species richness of floral resources and pollinators, as well as site coordinates. We gathered the data at site level and at the best possible resolution (e.g. without pooling the sampling occasions). Despite all of these, the case studies have different sampling protocols and data structures. Hence, to analyse these datasets, we merged and pooled similar variables to uniform variables, e.g. wild bees (including all the sampled bees without honey bees, sometimes in a broader sense of Hymenoptera), butterflies (sometimes in a broader sense of Lepidoptera), flower-visiting beetles (sometimes in a broader sense of Coleoptera), abundance of floral resources (as number of flower units or flower covers) and vegetation height (average or maximum). Furthermore, we calculate the sum abundance and morphospecies richness for the total pollinators where >1 pollinator group was sampled and was not given the sum pollinators.

Altogether, in the case of the urban dataset, we have the following variables: vegetation height (6 datasets), vegetation green cover (5 datasets), floral resource *abundance* (*16* datasets) and *species richness* (*10* datasets), total pollinator *abundance* (*16* datasets) and *species richness* (*14* datasets), honeybee *abundance* (*15* datasets), bumblebee *abundance* (*15* datasets) and species *richness* (*9* datasets; please note, the numbers are in the same order below), wild bees (*14* and *10*), butterflies (*17* and *12*), hoverflies (*11* and *5*), other flies (*4* and *2*), flower-visiting beetles (*4* and *3*).

Altogether, in the case of the protected dataset, we have the following variables (the numbers are in the same order as before): vegetation height (12), vegetation green cover (10), floral resource *abundance* (*12*) and *species richness* (*7*), honeybee *abundance* (*8*), bumblebee *abundance* (*8*) and species *richness* (*7*), wild bees (*18* and *14*), butterflies (*20* and *21*), hoverflies (*8* and *7*), flower-visiting beetles (*4* and *3*).

2.1.5. Statistical analyses

We investigated the urban and protected datasets separately. To analyse datasets from different origins on the same, comparable level, we scaled all values to 0–1 at the level of sampling occasions for each analysed variable, guilds, within the case studies. We scaled and analysed separately the following response variables: vegetation cover and height, the abundance and species richness of floral resources and pollinators at guild levels. We applied generalized linear mixed models (GLMM; Venables and Ripley 2002; Zuur et al. 2009). We used beta distribution by the 'ordbeta' family that fits continuous data in the closed interval between 0 and 1, including also the lower and upper bounds (Kubinec 2023). First, to reveal the general effects of pollinator-promoting interventions, we combined data for all the case studies but analysed separately the gathered variables (e.g. different guilds). Pollinator-promoting intervention (treatment vs. control sites) was the explanatory variable, while the case studies and the sampled sites (1|study/site), as well the study years and sampling periods (1|year/period) were treated as nested random factors. Second, to reveal the differences specific to case studies, we fitted similar models that also estimate the differences between treatment and control sites for each dataset separately, while handling them in one model, improving standard error estimates and avoiding increased Type I errors due to multiple testing. In these models, the explanatory variables were the case studies with reference to zero, and the interaction between case studies and pollinator-promoting intervention (i.e., ~0+study+study:intervention), while the study sites, years and sampling periods were treated as random factors. From these models, we obtain odds ratio estimates and 95% confidence intervals, and we plot them. We used the R statistical environment (v.4.2.1; RCoreTeam 2022), packages ‘glmmTMB’ v.1.1.5 for GLMMs (Brooks et al. 2017)

2.2. Results of the re-analytical data-syntheses

We gathered altogether 60 (28 urban and 32 protected habitat-focused) case study datasets (Figure 1). These studies originated from the whole continent, but there are hotspots of datasets, while also regions without any received data (Figure 1). The exact identification of these reasons may be important in the future, in the context of EU projects, contributors, focus areas, and calls for proposals.

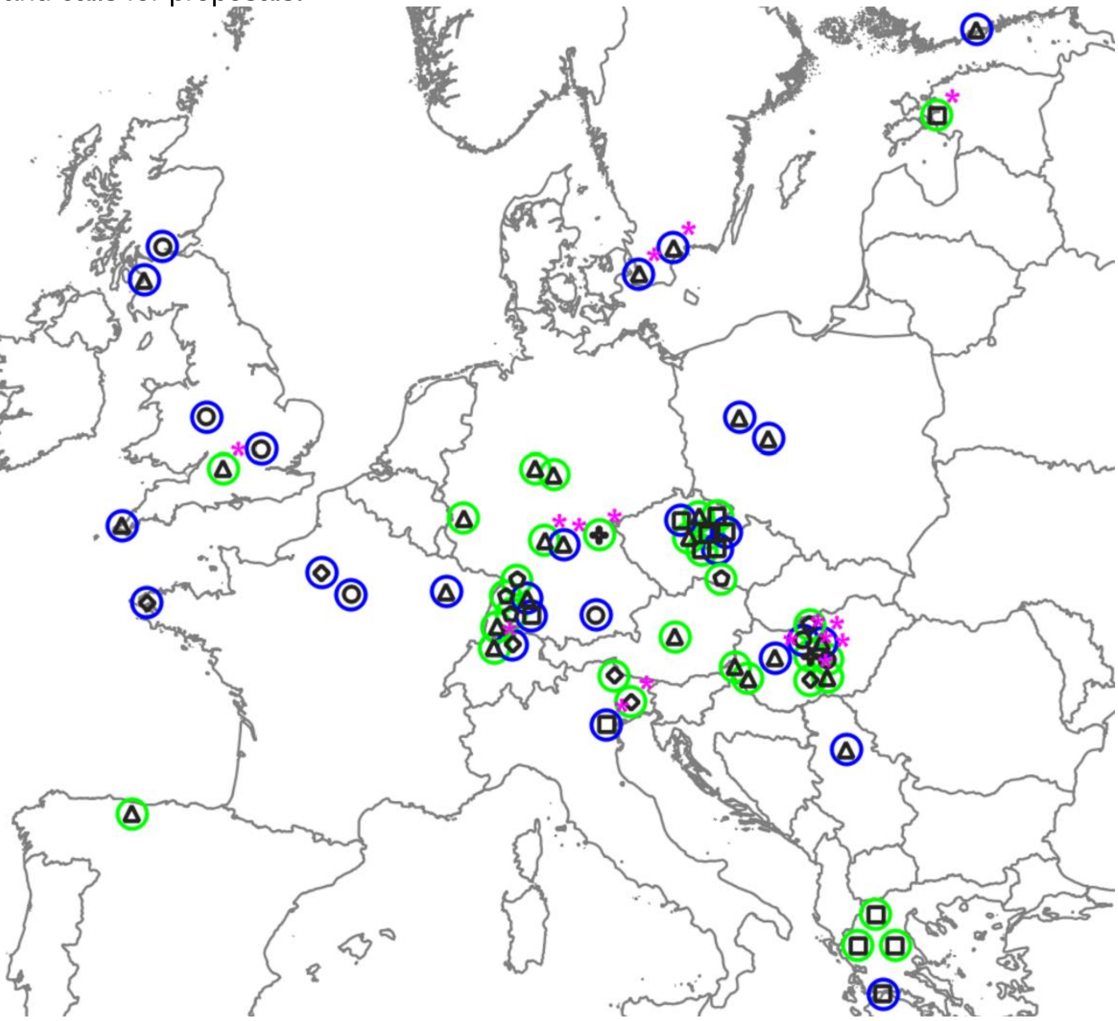

Figure 1. The gathered datasets within Europe. Circles present the involved studies by their averaged coordinates, sampled cities or central point of the sampled country coordinates, which are also jittered scarcely for better visualization. Topics: blue (urban habitats) and green (protected habitats). Treatment types: square (abandonment); circle (flower sowing supplemented with nesting boxes in one case); triangle (extensive mowing); rhombus (low management intensity); cross (extensive grazing); pentagon (others such as gap creation, extensive mulching, and uprooting+girdling). The pink star indicates that the dataset is provided by a Safeguard partner.

The gathered urban datasets cover 15 years (2006-2022) and 12 countries (Figure 1) with altogether 1,052 sampling sites (many were sampled by multiple years and occasions) within Europe (Table 1). Most of the investigated pollinator-promoting interventions were extensive mowing and abandonment (19) or flower sowing (6), but some combined practices (as a low management intensity, 3) also occurred (Table 1). More than half of the study designs were originally control-treatment approaches (Table 1). The rest were categorised for this study based on expert opinion or a treatment gradient (e.g. management intensity changed along a gradient within the city; Table 1).

The gathered protected datasets cover 19 years (2003-2022) and 10 countries (Figure 1) with altogether 723 sampling sites (many were sampled over multiple years and occasions) within Europe (Table 2). Most of the interventions considered pollinator-promoting were extensive mowing or grazing (10), but mowing and grazing as a conservation practice also occurred (6), and abandonment was similarly often used (7; Table 2). The remaining types of intervention were very diverse in protected areas: combined practices (as a low management intensity, 3), gap creation (3), flower sowing (1), extensive mulching (1), and uprooting+girdling (1; Table 2).

On the urban topic, analysing the 28 case studies together, we did not find any significant negative pooled effect of pollinator-promoting interventions (Figure 2). While, they have positive significant effects on the vegetation height, floral resources, and most of the pollinator groups (except the abundances of honeybee and flower-visiting beetles, the species richness of hoverflies and other flies, where the analyses show non-significant results; Figure 2). In the urban landscapes, butterflies were the most studied pollinator group, while other flies and flower-visiting beetles were the least studied (Figure 2). However, at the level of case studies, there were some datasets where negative effects were found. The case studies individually often show non-significant results (see the thinner, colourful lines with symbols in Figure 2). While a high proportion of the studies on flower sowing and extensive mowing in parks and road verges show a significant result at the case study level.

As mentioned in the Methods, the protected datasets are in a preliminary phase (i.e. dataset under data cleaning) so we provide only preliminary results. Analysing the 32 case studies together, we did not find any significant negative pooled effect of pollinator-promoting interventions (Figure 3). While, they have positive significant effects on the abundances and species richness of wild bees and butterflies, where the analyses show non-significant results; Figure 3). In the protected landscapes, butterflies were the most studied pollinator group similar to urban settlements, while flower-visiting beetles were the least studied, and other flies were not studied at all (Figure 3).

Table 1. Attributes of the gathered urban datasets. Pollinators: honeybee (hb), bumblebee (bb), wildbee (wb), hoverfly (hf), otherfly (of), butterfly (bf), and flower-visiting beetle (fb). Floral resources: flower abundance (flo abu) and flower species richness (flo sp). Vegetation: vegetation height (veg hei) and vegetation cover (veg cov).

Country	Year	Management	Pollinators	Floral resources	Vegetation
Czech Republic	2011	extensive mowing/ abandonment	bf, fb	flo abu	NA
Czech Republic	2017	extensive mowing/ abandonment	bf, fb	flo abu	NA
Czech Republic	2017	abandonment	hb, wb, bf	flo abu	NA
Finland	2010, 2012-2013	extensive mowing as conservation practice	wb	NA	NA
France	2009	low management intensity (combined)	bf	NA	NA
France	2009-2011	low management intensity (combined)	bb, bf	flo sp	NA
France	2010	flower sowing +nesting boxes	bb, hb, wb, hf, bf, of	NA	NA
France	2021	extensive mowing	bb, hb, wb, hf, bf, fb, of	flo abu	veg hei
Germany	2011	extensive mowing	bf	NA	NA
Germany	2014-2015	abandonment	wb	NA	NA
Germany	2020	extensive mowing	bb, wb, hf	flo abu, flo sp	NA
Germany	2020-2021	flower sowing	bb, hb, wb	flo abu, flo sp	NA
Greece	2015	abandonment	bf	NA	NA
Hungary	2022	extensive mowing	bb, hb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
Hungary	2022	flower sowing	bb, hb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
Hungary	2022	extensive mowing	bb, hb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
Italy	2022	abandonment	wb	flo abu	veg cov
Poland	2014-2016	extensive mowing	bb, hb, wb	NA	NA
Poland	2016	extensive mowing	bb, hb, wb, hf, bf	flo sp	veg hei, veg cov
Serbia	2017	extensive mowing	hb, wb	flo abu	NA
Sweden	2006	extensive mowing	bf	NA	NA
Sweden	2021	extensive mowing	bf, wb	NA	NA
Switzer-land	2015	low management intensity (combined)	bb, hb, wb	flo abu	NA
UK	2012	flower sowing	bb, hb, wb, hf, bf, of	flo abu	NA
UK	2014	flower sowing	wb, bf	flo abu, flo sp	NA
UK	2016-2017	flower sowing	bb, hb, wb, hf	NA	NA
UK	2018	extensive mowing	bb, hb, hf, bf, fb, of	flo abu, flo sp	veg hei
UK	2022	extensive mowing	bb, hb, hf	flo abu, flo sp	NA

Table 2. Attributes of the gathered protected datasets. Pollinators: honeybee (hb), bumblebee (bb), wildbee (wb), hoverfly (hf), butterfly (bf), and flower-visiting beetle (fb). Floral resources: flower abundance (flo abu) and flower species richness (flo sp). Vegetation: vegetation height (veg hei) and vegetation cover (veg cov).

Country	Year	Management	Pollinators	Floral resources	Vegetation
Austria	2015-2016	mowing as conservation practice	bb, hf	flo abu	NA
Czech Republic	2011	abandonment	hb, bb, wb	NA	NA
Czech Republic	2015	extensive mowing as conservation practice	hb, bb, wb	NA	NA
Czech Republic	2015	extensive mowing as conservation practice	wb	NA	NA
Czech Republic	2015	gap creation	hb, bb, wb, bf, fb	NA	NA
Czech Republic	2022	extensive mowing	wb, bf, fb	flo abu	NA
Czech Republic	2022	extensive mowing	wb, bf, fb	flo abu	NA
Estonia	2022	abandonment	hb, bb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
Germany	2010	extensive grazing	wb	flo abu, flo sp	NA
Germany	2010	extensive mowing/grazing as conservation practice	bf	NA	NA
Germany	2015	extensive mowing/grazing as conservation practice	bf	flo sp	veg hei, veg cov
Germany	2016	extensive mowing/grazing as conservation practice	bf	NA	NA
Germany	2017	extensive mulching	wb, hf, bf, fb	NA	NA
Germany	2018	extensive mowing/grazing as conservation practice	bf	NA	NA
Germany	2022	extensive mowing/grazing	hb, bb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
Germany	2018-2019	uprooting+girdling	wb	NA	veg cov
Germany	2019-2020	gap creation	wb	flo sp	veg cov
Greece	2007	abandonment	bf	flo abu	veg hei, veg cov
Greece	2008	abandonment	bf	flo abu	veg hei, veg cov
Greece	2022	abandonment	bf	flo abu	veg hei, veg cov
Hungary	2003	extensive grazing	wb	NA	veg hei
Hungary	2018	extensive mowing/grazing	bf	NA	NA
Hungary	2019	gap creation	wb	NA	NA
Hungary	2022	low management intensity (combined)	hb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
Hungary	2007-2008, 2010, 2017, 2021	extensive mowing	bf	flo abu	NA
Hungary	2016-2020	extensive mowing/grazing	bf	NA	NA
Hungary	2020-2022	flower sowing	wb, hf, bf	NA	NA
Italy	2010	low management intensity (combined)	bf	NA	NA
Italy	2019	low management intensity (combined)	bf	NA	veg hei
Spain	2019	extensive mowing as conservation practice	bf	NA	veg hei
Switzerland	2022	extensive mowing	hb, bb, wb, hf, bf	flo abu, flo sp	veg hei, veg cov
UK	2022	extensive mowing/grazing	hb, bb, wb, hf, bf	NA	veg hei

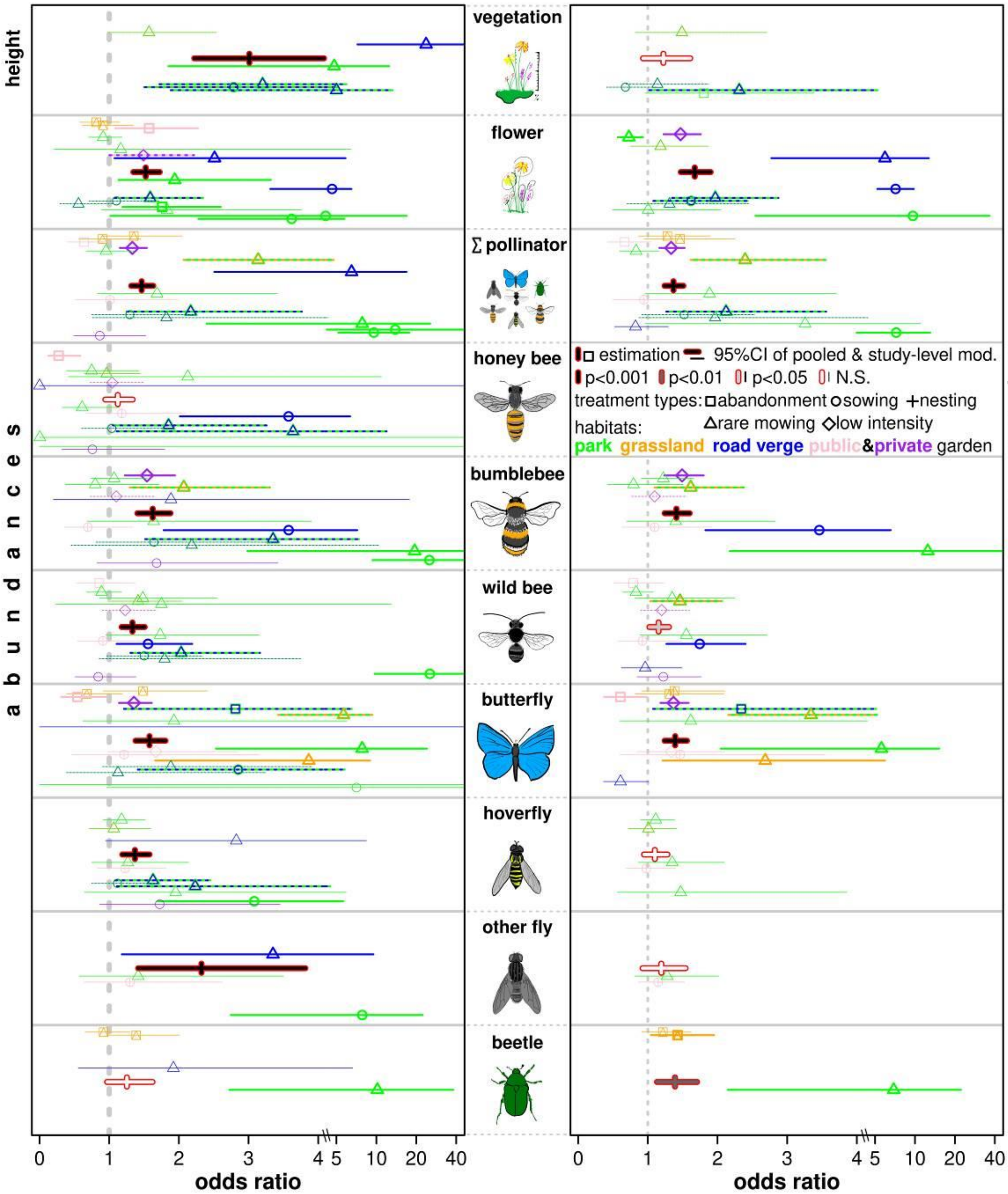

Figure 2. Re-analytical data-synthesis of pollinator-promoting interventions in European urban areas. Results on vegetation height and cover, flower and pollinator abundances and species richness present the model estimations and 95% confidence intervals of the odds ratio from the GLMMs both for pooled (thicker lines with red outline) and case study level (thinner, colourful lines with symbols) analyses. The pooled analyses (thicker lines with red outline) were filled with white (N.S.); pale grey ($p < 0.05$); dark grey ($p < 0.01$); and black ($p < 0.001$). Case study-level models were presented with thin lines (N.S.) and bold lines ($p < 0.05$;). Treatment types of case studies are presented by square (abandonment); triangle (extensive mowing); triangle+square (extensive mowing+abandonment); circle (flower sowing); circle+cross (flower sowing+nesting boxes); rhombus (low management intensity). Vegetation type: green (parks including urban green spaces); orange (urban grasslands including ruderal habitats and a few laws); blue (road verges); pink (public gardens including orchards); purple (private gardens); dashed line and double colour (more than one vegetation type in a dataset). X-axes are broken where the odds ratio is above value four and changed to the log scale for better visualization.

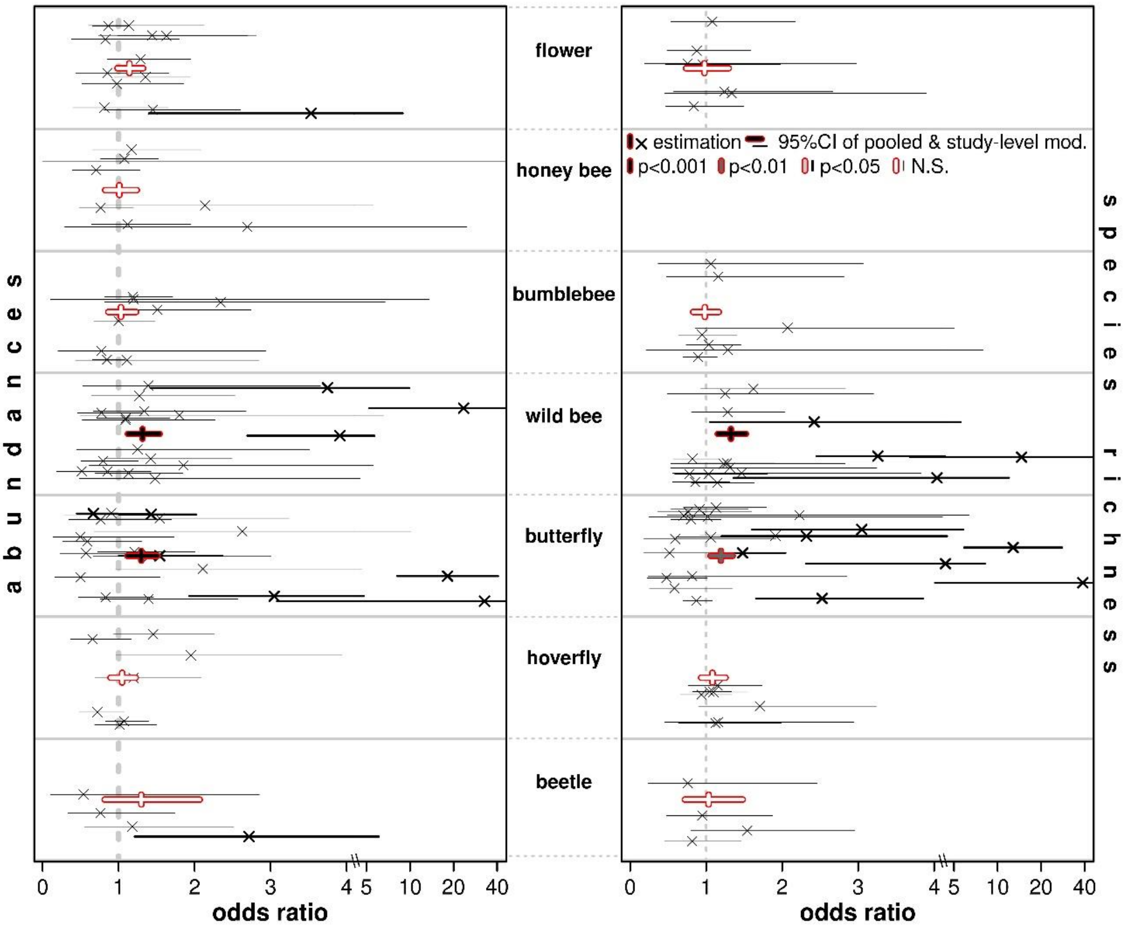

Figure 3. Re-analytical data-synthesis of pollinator-promoting interventions in European protected areas. Preliminary results on flower and pollinator abundances and species richness presenting the model estimations and 95% confidence intervals on the odds ratio from the GLMMs both for pooled (thicker lines with red outline) and case study level (thinner, black lines with × symbols) analyses. The pooled analyses (thicker lines with red outline) were filled with white (N.S.); pale grey ($p < 0.05$); dark grey ($p < 0.01$); and black ($p < 0.001$). Case study-level models were presented with thin lines (N.S.) and bold lines ($p < 0.05$;). X-axes are broken where the odds ratio is above value four and changed to the log scale for better visualization.

3. Urban case studies in Hungary

3.1. Methods

3.1.1. Studied pollinator-promoting interventions

To show the Eastern European situation of urban pollinator-promoting interventions, we studied the first steps of these approaches in two Hungarian cities (Süle et al. 2023a). Veszprém city (administrative county centre in the Veszprém Plateau; ~266 m a.s.l.; 126.9 km2; 58,153 inhabitants, Wikipedia 2023b; 10.3°C annual averages and 532 mm annual total precipitation based on 10-year (2012–2021); Vmeteo 2022) started the 'Wildflower Veszprém' project in 2017 with reduced mowing frequency (3 mowings/year instead of more than 3) in seven test areas (hereafter: extensive mowing in Veszprém).

In Budapest (the capital city within Buda Hills and Pest Alluvial Plain; ~105 m a.s.l.; 525.1 km2; 1,706,851 inhabitants, Wikipedia 2023a; 13.2°C annual average and 538 mm annual total precipitation based on 10-year (2012–2021); KSH 2022), an extensive grassland management program started in 2021 within the 'Wildflower Budapest' project on twenty-two insect-friendly (in total ~28 ha) areas by the Horticultural Division of Budapest Public Utilities (Kovács et al. 2021). The mowing frequency in the mown grasslands was reduced to 1-2 mowing/year instead of more than two to enable wild herbaceous plants to develop flowers and seeds, and to disperse (hereafter: extensive mowing in Budapest).

Independently from the Wildflower Budapest project, the 12th District of Budapest started the 'Bee-friendly District' program in 2018 (Hegyvidéki Önkormányzat 2020). They have been creating an increasing number of annually sown bee pastures (hereafter: flower sowing in Budapest). In this study, we sampled six sites sown with a herbaceous seed mixture of 44 native and adventive plant species originating from a Hungarian distributor (Mix1; Sipos 2020), and another six sites sown with an ornamental seed mixture of 40 different flower varieties originated from a Dutch distributor (Mix2; flower your place 2023; without detailed species list, containing at least 10 North American annual species). The sown sites were scarified and re-sown in spring every year, and regularly watered and weeded during the season. From 2023, locally adapted native seed mixtures have been sown containing mostly perennial species. This new perennial native mixture can ensure the long-term establishment of sown areas without annual soil disturbance, which could also reduce the costs and increase the benefits for ground-nesting bees, overwintering pollinators, and herbivore larvae using the sown species as host plants.

3.1.2. Study sites in two cities in Hungary

In 2022, we selected 5 site pairs of treatment (3 mowings/year) and control (4-7 mowings/year; conventionally mown parks) for extensive mowing in Veszprém, 10 site pairs of treatment (1-2 mowings) and control (3-4 mowings/year; conventionally mown parks and road verges) for extensive mowing in Budapest, and 12 site pairs of treatment (sown bee pastures) and control (conventionally mowed parks and road verges) for flower sowing in Budapest (Figure 4). During the site selection, we aimed to ensure that all sites were as similar as possible in size, exposure, vegetation type, and potential human impact while keeping paired sites close to each other. However, note that the appropriate controls for flower sowing in Budapest probably would be areas that were watered (and weeded) in the same way as the sown sites. However, such a comparison was not possible because most of the public road verges and parks are not watered in the same way as the sown sites. The same sampling was carried out in 2023 as well, but some sites were excluded/included compared to 2022.

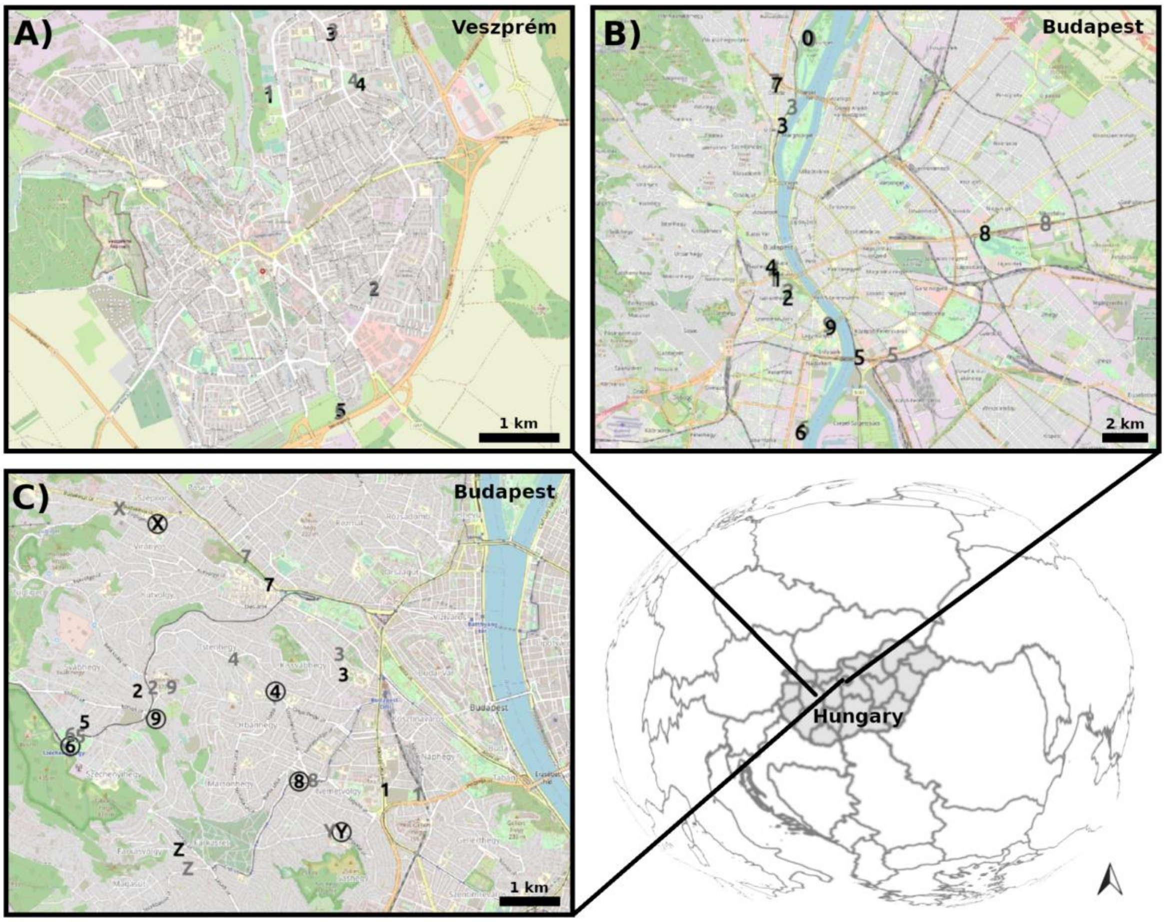

Figure 4. The sampling sites within Hungary in 2022: extensive mowing in Veszprém (A), extensive mowing in Budapest (B) and flower sowing in Budapest (C). Numbers and letters represent site pairs. Black letters and numbers are the treatment sites, while grey letters and numbers are the control sites. The uncircled numbers represent the sites sown with Mix1, while the circled numbers are the sites sown with Mix2 in the C part of the Figure. Map data 2022 © OpenStreetMap (Süle et al. 2023a).

3.1.3. Sampling on vegetation, flowers and pollinators

We sampled the whole season from spring to autumn with five sampling occasions (end of April, mid-May, mid-June, mid-July, and end of August) in 2022 and 2023. The control-treatment site pairs were sampled haphazardly after each other on the same day to have as similar weather and daytime conditions as possible, decreasing the influence of the daily rhythm of flowers and pollinators. We sampled the vegetation, floral resources, and pollinators in 5 circular 160 cm diameter (2 m^2) plots per site on each sampling occasion (using a similar, but further developed sampling method than the 'Fit Count' of UKCEH 2021). We placed the circle sample plots haphazardly paying attention to avoid shade within the sites. Within these circular plots, we measured the average vegetation height [cm] using a tape measure, estimated the green and dry vegetation covers [%] and some further variables such as trampling [%], and nest holes. We recorded the number of flower units per morphogroups of all currently flowering, insect-pollinated herbaceous species (Szigeti et al. 2016; UKCEH 2021). Morphogroups refer to individuals (i.e. flowers and pollinators) that can be distinguished visually by phenotypic characteristics such as colour, size, body type, hairiness, patterns, etc. Furthermore, we recorded visually the number of pollinators at morphogroup levels during continuous 5 minutes per plot without catching the animals and stopping the stopwatch while writing information. Pollinators were also grouped into major guilds such as honey bees, bumblebees, solitary bees, hoverflies, butterflies, and moths. We conducted the samplings only in suitable weather conditions: rain-free hours; dry vegetation; temperature: 20-30°C (except in April, when we sampled >13°C in full sunshine, and >16°C in partly cloudy weather); wind: <15km/h (verified by an Extech 45158 mini thermo-anemometer (Teledyne FLIR LLC; Wilsonville, Oregon, USA)), in daytime (April: 9.30 AM – 4.30 PM; May: 9.00 AM – 5.00 PM; June and July: 8.30 AM – 6.00 PM; August: 9.00 AM – 5.00 PM; Süle et al. (2023a))

3.1.4. Challenges due to drought and imperfect management

The year 2022 was extreme in terms of weather conditions combined (and probably interrelated) with some inaccuracies in the site management of treatments. At the drought-monitoring station (Pusztaszabolcs) between Budapest and Veszprém, the drought index was above 3 (extreme drought) on 24 days (Fiala et al. 2018; ODWMS 2023) between 1 April and 1 September 2022. In contrast, there was not a single day in the previous 5 years when the drought index was above 3 (ODWMS 2023). Some management inaccuracies have occurred in both kinds of management methods. Part of these management inaccuracies are related to the drought, e.g. watering might favour the more resistant weeds in the sown areas, while intensive mowing was not needed. Because without precipitation, the vegetation did not grow well, so frequent mowing was not necessary. In addition, the vegetation in the extensively mowed sites did not develop much better and might not produce many more flowers than the control sites. Off-schedule mowings occurred in the program of extensive mowing in Veszprém and extensive mowing in Budapest, while sometimes un-removed hay also occurred in the latter. In the case of sowing in Budapest, probably a too strong watering in the initial period and a lack of proper weeding caused worse conditions than expected in some sites compared to previous years (pers. obs. of the local authority maintaining the intervention). Due to the drought and management inaccuracies, the following treatment sites of sowing in Budapest program have been withdrawn by the local authority from the pollinator-promoting project (i.e. vegetation has been cut and not watered) after mid-July: 4, 6, 8, Y (Figure 4). However, we continued the sampling on these sites despite the cessation of the original management thus; they were sampled as many times as the other sites.

The year 2023 has better weather conditions from the view of flowers and pollinators, e.g. higher amount of precipitation, but the warmest year in Hungary in the 21st century (HungaroMet 2024). The drought of 2022 affected both years but differently. During the drought year (2022), the lack of food sources may cause pollinators to live for a shorter age and produce fewer offspring. Thus, drought is also impacting their abundance in the following year(s) (e.g. 2023), even if floral resources are already available. In addition, after the drought of 2022, the heavy rainfall of the 2023 spring and summer could have stimulated the plants to excess flowering and growth. This process could also have occurred at our control sites, not just in the treatments, producing a surplus of flowers in every urban green area. Also, there was less mowing in the conventionally managed green areas in 2022 due to the drought, which low management intensity may have also facilitated the development of the vegetation for the next year. Thus, the seasonal and long-term effects of consecutive years of extreme drought and rainfall draw attention to the need for long-term monitoring also within cities.

3.1.5. Statistical analyses of the Hungarian case studies

For analyses of the three case studies, we applied the original plot-level data. We tested differences between treatment and control sites in height and green cover of vegetation; total abundance and morphogroup richness of floral resources and pollinators during the five sampling occasions. For this, we applied generalized linear mixed models (GLMMs) using Gaussian distribution on the ten-based logarithm of the vegetation height (adding one to all values before transformation due to zeros), Beta distribution on the vegetation green cover, zero-inflated Poisson distribution on abundances and morphogroup richness as the best-fitted distributions (Zuur et al. 2009). We added a small value (0.000001) to all zero and subtracted a small value (0.000001) from all values one of vegetation green cover to be able to analyse ratios because Beta distribution does not accept exact 0 and 1 values. The response variables were vegetation height and green cover; total abundance, morphogroup richness of floral resources and pollinators. The explanatory variables were the sampling occasions (i.e. April, May, June, July, and August as factors), the treatment, and their interactions. We included the site code within the site pair code into the model as nested random factors to treat the potential spatial autocorrelation by the sampling structure (i.e. control-treatment pairs of sites were close in space and sampling time) and the pseudoreplication (i.e. five replications during one sampling occasion) within the site. We analysed separately the three case studies. We evaluated the seasonal changes graphically. For this, all sampling occasions of each variable were averaged for the treatments, controls, and all sites separately, for each case study, and presented on a figure by these descriptive statistics. We used the R statistical environment (v.4.2.1; RCoreTeam 2022), packages 'glmmTMB' v.1.1.5 for GLMMs (Brooks et al. 2017), spdep v.1.2-8 for Moran I tests (Bivand et al. 2015), MuMIn v.1.47.1 for model averaging (Barton 2023). For more details and more analyses, please see (Süle et al. 2023a).

3.2. Results of the urban case studies in Hungary

In Hungarian case studies, during two years, we sampled about 2,700 plots during net 220 hours (net 40 hours (extensive mowing in Veszprém), 80 hours (extensive mowing in Budapest), and 100 hours (sowing in Budapest)), where we counted more than 60 thousand floral units and observed more than 10 thousand pollinators in total. Pollinators belonged mostly to solitary bees (by ~60%), then to hoverflies (~10%), butterflies (~10%), honey bees (~8%), bumblebees (7%), and moths (1%) in these sampled urban sites (based on the data from 2022; see more details in Süle et al. (2023a)).

3.2.1. Extensive mowing in Veszprém

In 2022, the vegetation height and green cover were significantly higher in treatment sites during the season (except in May and August) compared to the controls (Figure 5). All variables in June and all variables except flower abundance and morphogroup richness in July showed significant differences in favour of the treatment sites, while just vegetation height and green cover, pollinator abundance and morphogroup richness in April. In contrast, one variable, the flower abundance was higher in the control sites in May and August (Figure 5).

For the seasonal changes, the vegetation height and green cover drastically decreased in the treatment sites for the second half of the season (Figure 5). In the control sites, the vegetation green cover notably increased from July to August (Figure 5). The flower and pollinator variables also followed the decreasing trend with a peak in April and June (Figure 5). At the end of the season, both the control and the treatment sites had similar values for all variables (Figure 5).

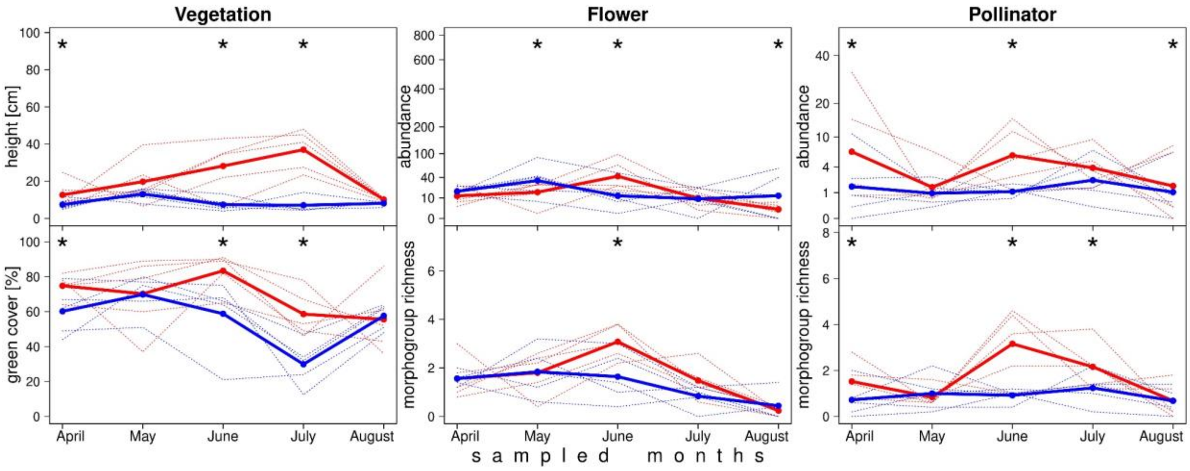

Figure 5. The seasonal changes in the vegetation height and green cover, flower and pollinator abundance and morphogroup richness for the *Extensive mowing in Veszprém* in 2022. The blue connected dots indicate the average of the control sites, while the red connected dots indicate the average of treatment sites. Dashed lines represent each site separately (blue: controls, red: treatments). Stars indicate significant ($p < 0.05$) differences between the controls and treatments according to GLMMs.

In 2023, the vegetation height and green cover were significantly higher in treatment sites in the middle of the season (except in July) compared to the controls (Figure 6). All variables in June and all variables except flower abundance in May showed significant differences in favour of the treatment sites, while in April and August, no variables were significantly higher in treatment sites. In addition, just one variable, the vegetation height was higher in the treatment sites in July (Figure 6). In contrast, flower morphogroup richness showed significant differences in favour of the control sites in August (Figure 6).

For the seasonal changes, all variables drastically decreased in the treatment sites for the second half of the season (Figure 6). The flower and pollinator variables also followed the decreasing trend with a peak in April and June, similar to 2022 (Figure 6). In the control sites, the flower abundance and morhogroup richness notably increased to July (Figure 6). At the end of the season, both the control and the treatment sites had similar values for all variables, similar to 2022 (Figure 6).

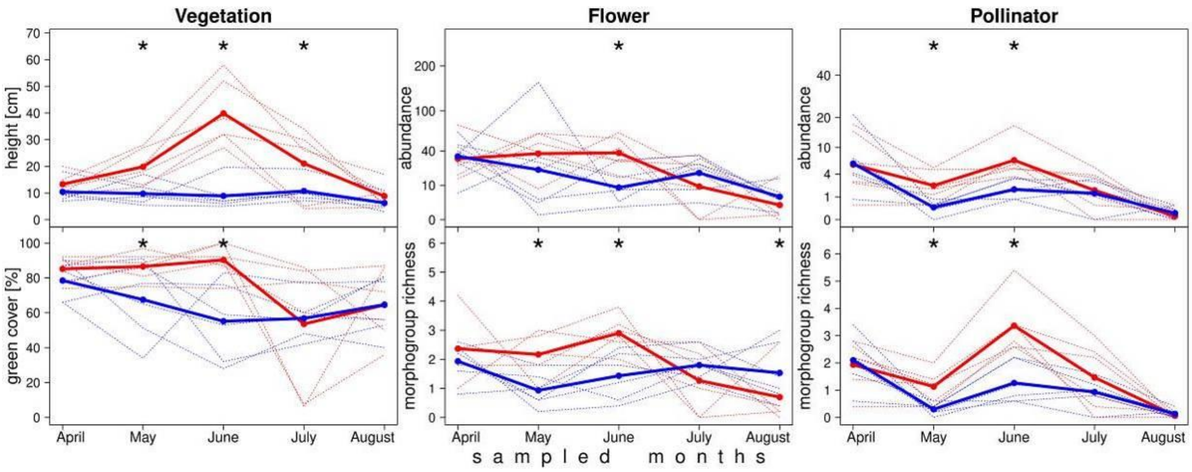

Figure 6. The seasonal changes in the vegetation height and green cover, flower and pollinator abundance and morphogroup richness for the *Extensive mowing in Veszprém* in 2023. The blue connected dots indicate the average of the control sites, while the red connected dots indicate the average of treatment sites. Dashed lines represent each site separately (blue: controls, red: treatments). Stars indicate significant ($p < 0.05$) differences between the controls and treatments according to GLMMs.

3.2.2. Extensive mowing in Budapest

All significant variables were higher for the treatment sites during the season in 2022. The vegetation height was consistently higher in all sampling occasions, but the vegetation green cover was higher only in July in the treatment sites compared to the controls (Figure 7). Some variables of the floral resources also showed significant differences in favour of the treatment sites (e.g. higher flower abundance in April and July; higher morphogroup richness in all sampling occasions except August; Figure 7). Pollinator abundance and morphogroup richness tended to be higher in the treatment sites in the beginning and middle of the season (April and June), while in May and July, only the pollinator abundance and morphogroup richness were higher in the treatment sites, respectively (Figure 7). We did not find any significant difference between the treatment and control sites in August except for the vegetation height (Figure 7).

Regarding the seasonal changes, the control and treatment sites showed similar patterns for all variables throughout the season, except the vegetation height, which was consistently low in the control sites but was higher and constant from May to July in the treatment sites (Figure 7). The vegetation green cover drastically decreased in the second half of the season in all sites (Figure 7). The flower and pollinator variables also followed this decreasing trend with a slight peak in June and also in April, respectively (Figure 7). At the end of the season, both the control and the treatment sites had similar values for all variables (Figure 7).

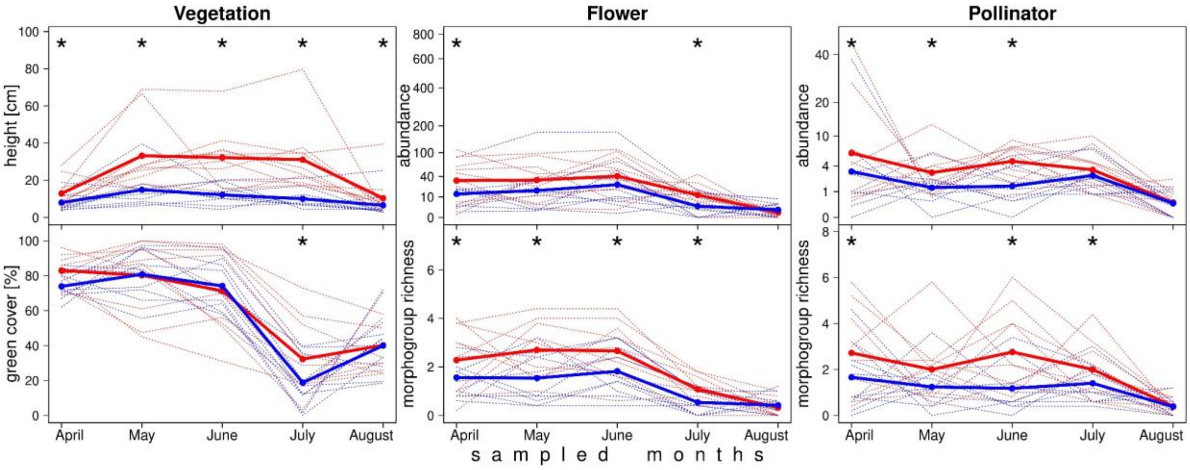

Figure 7. The seasonal changes in the vegetation height and green cover, flower and pollinator abundance and morphogroup richness for the *Extensive mowing in Budapest* in 2022. The blue connected dots indicate the average of the control sites, while the red connected dots indicate the average of treatment sites. Dashed lines represent each site separately (blue: controls, red: treatments). Stars indicate significant ($p < 0.05$) differences between the controls and treatments according to GLMMs.

All significant variables were higher for the treatment sites during the season in 2023. The vegetation height was consistently higher in all sampling occasions, but the vegetation green cover showed no significant differences between the treatment and control sites during the season (Figure 8). The floral resources variables showed no significant differences in favour of the treatment sites (except flower morphogroup richness in July; Figure 8). Pollinator variables tended to be higher in the treatment sites with significant differences except in April (Figure 8).

Regarding the seasonal changes, the control and treatment sites showed similar patterns for all variables throughout the season, except the green cover and the floral resources, which were sometimes higher in the control sites (e.g. green cover in August, flower abundances in May, and flower morphogroup richness in May and June; Figure 8). The vegetation green cover showed very similar values in all sites during the season (Figure 8). The pollinator variables showed a decrease in May and the end of the season with a slight peak in April and June, similar to 2022 (Figure 8).

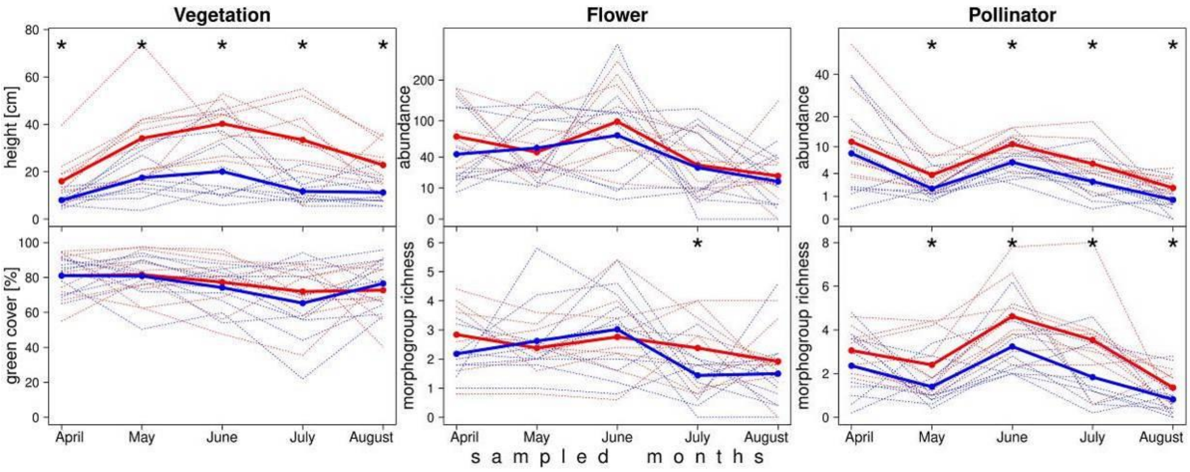

Figure 8. The seasonal changes in the vegetation height and green cover, flower and pollinator abundance and morphogroup richness for the *Extensive mowing in Budapest* in 2023. The blue connected dots indicate the average of the control sites, while the red connected dots indicate the average of treatment sites. Dashed lines represent each site separately (blue: controls, red: treatments). Stars indicate significant ($p < 0.05$) differences between the controls and treatments according to GLMMs.

3.2.3. Sowing in Budapest

In 2022, in the first half of the season, in the control sites, the vegetation green cover and flower abundance were higher in April, and all the vegetation and floral resource variables were higher in May compared to the treatment sites (Figure 9). In June, the vegetation height, flower abundance, and pollinator abundance were higher in the treatment sites (Figure 9). In the second half of the season (July and August), all variables were significantly higher in the treatment sites, except the vegetation green cover and the flower abundance in August (Figure 9).

For the seasonal changes, the vegetation height slightly decreased, while the green cover drastically decreased in the control sites for the second half of the season (Figure 9). In the treatment sites, the vegetation height and green cover increased from May to July, which was suppressed by the withdrawal of some sites from the pollinator promotion until our sampling in August (Figure 9). The floral resource and pollinator variables followed the same trend as the vegetation variables in the control and treatment sites, respectively (Figure 9). There was a peak in all the flower and pollinator variables in the control sites in April and June, while the treatment sites showed the flower and pollinator peak in the second half of the season (except August; Figure 9).

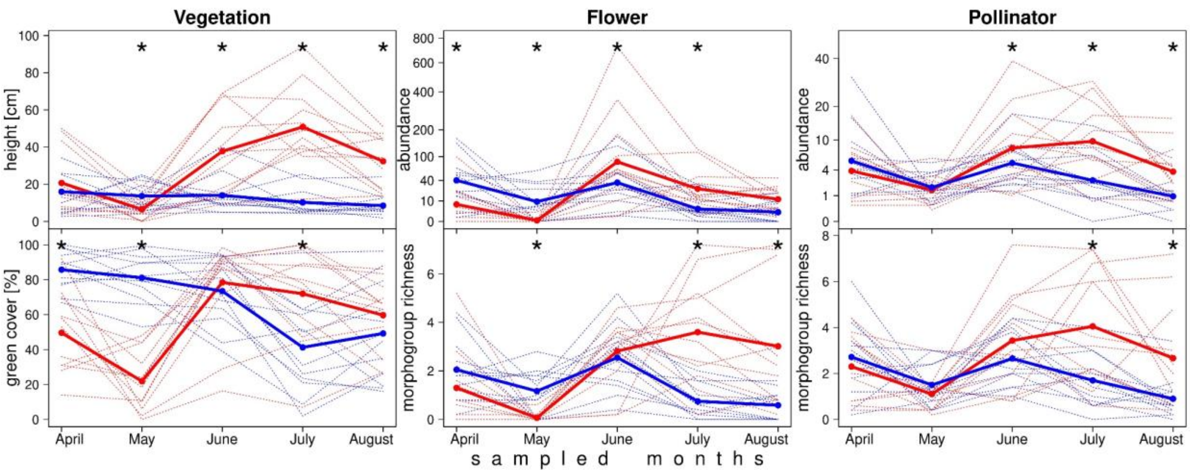

Figure 9. The seasonal changes in the vegetation height and green cover, flower and pollinator abundance and morphogroup richness for the *Sowing in Budapest* in 2022. The blue connected dots indicate the average of the control sites, while the red connected dots indicate the average of treatment sites. Dashed lines represent each site separately (blue: controls, red: treatments). Stars indicate significant ($p < 0.05$) differences between the controls and treatments according to GLMMs.

In 2023, in the first half of the season, in the control sites, all vegetation and floral resource variables were significantly higher in April, and the floral resources were also significantly higher in May compared to the treatment sites (Figure 10). In June, the floral resource and pollinator variables were higher in the treatment sites (Figure 10). In the second half of the season (July and August), all variables were significantly higher in the treatment sites, except the vegetation green cover in August, flower abundance in July and August, and pollinator abundance in August (Figure 10).

For the seasonal changes, the vegetation variables varied during the season in the control sites, while the floral resource and pollinator variables decreased in June and May, respectively (Figure 10). There was a peak in the floral resource variables in the control sites in April and August, while pollinator variables also showed a peak in April, but the second peak was in June and July. In the treatment sites, all variables increased from April to the middle or the end of the season (Figure 10).

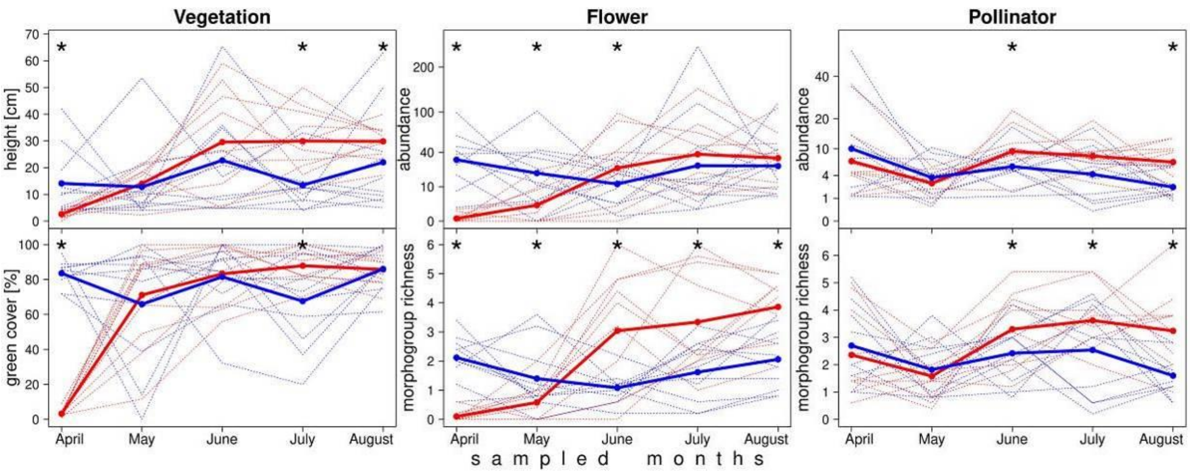

Figure 10. The seasonal changes in the vegetation height and green cover, flower and pollinator abundance and morphogroup richness for the *Sowing in Budapest* in 2023. The blue connected dots indicate the average of the control sites, while the red connected dots indicate the average of treatment sites. Dashed lines represent each site separately (blue: controls, red: treatments). Stars indicate significant ($p < 0.05$) differences between the controls and treatments according to GLMMs.

4. Discussion

In the Task 4.2. (entitled: 'Moving out of the farmland: making Natura 2000 areas and public space more valuable for pollinators') of the Safeguard project, our main objective was to describe and synthesise the main patterns of the impact of pollinator-promoting interventions in European urban and protected areas, while with the Hungarian case studies, we would like to draw attention to Eastern European patterns and conditions.

4.1. Re-analytical data-synthesis

The studied pollinator-promoting interventions, management techniques, and restoration programmes have a generally positive effect based on the gathered datasets but vary by the studied parameters, pollinator guilds, and probably by the influence of the year-to-year and regional conditions. However, the purpose of a re-analytical data-synthesis is also to explore the role of unexpected influences and discover what we are not yet aware of. It would also be important to evaluate the temporal factors on the gathered dataset for the re-analytical data-synthesis. But at this stage of the analyses, we see a large variance in the random factors handling years and observation occasions, which also strongly characterizes the important role of temporality in a dynamically changing system dominated by flowers and insects (Rasmussen et al. 2013; Guzman et al. 2021; Resasco et al. 2021).

During the analysis of primary data, we were keen to explore what previous studies had focused on and what knowledge gaps could be identified. Based on the reviews of Baldock (2020) and Glenny et al. (2022), several local- and landscape-scale solutions exist in urban settlements and public semi-natural habitats to promote pollinators, however, just a few were studied by the gathered datasets. For example, bee hotels recently widespread pollinator-promoting intervention whose effectiveness is hardly known (Rahimi et al. 2021). However, Fortel et al. (2016) reported that bee hotels can be efficient but they also host parasites and favour invasive species, therefore need to be used with caution. Besides bee hotels, nest boxes are also considered to be effective nesting places for pollinators, but Rahimi et al. (2021) found that the use of nest boxes by bees has not been very successful and they recommend the use of bee hotels instead. Increasing the nesting sites for pollinators with artificial nests provides benefits only for cavity-nesting species, but ground-nesting species should be also promoted by bare ground surfaces in urban areas (Baldock 2020). Bare ground surfaces proved to be as important as potential nesting cavities in natural habitats (Potts et al. 2005), while bare ground surfaces are hardly considered and studied in urban areas (Hinners et al. 2012; Fortel et al. 2016; Theodorou et al. 2017). Besides the nesting resources, the habitat quality for pollinators can be efficiently improved by boosting food resources, where sowing or planting herbaceous species are widely used methods (Wenzel et al. 2020; Griffiths-Lee et al. 2022; Dietzel et al. 2023). The diversification of the vegetation structure through planting shrubs and trees for pollinators is also a rarely studies approach (Mach and Potter 2018), while they could provide shelter and shade (i.e. important micro-habitats and ecotones) for pollinators besides nectar and pollen (Majewska and Altizer 2020). Habitat quality can be also improved by reducing the use of chemicals, which approach has been widely applied in agriculture (Bommarco et al. 2013; Kovács-Hostyánszki et al. 2017). However, the importance of chemical reduction is hardly considered in cities, while they are used in many places and situations (such as herbicide, insecticide, and fertilizer as well as mosquito control in cities). Although we tried to collect several background variables for the re-analytical data-synthesis (e.g. pesticide and fertilisation use), just a few datasets included appropriate information without the real opportunity to analyse this topic. However, their importance is undeniable and many further studies are needed (e.g. the effect of mosquito control in cities on pollinator communities). The presented methods so far are all interventions established in present green areas, however, the increase of green spaces within highly urbanized areas is highly recommended (Baldock 2020). On the other hand, increasing the amount and size of green space is usually extremely hard in densely populated, highly built-up urban environments

(Jenks and Jones 2010). Establishing green roofs can be a suitable approach, whose pollinator-promoting impact is rarely compared with conventional urban green spaces (Braaker et al. 2017; Fournier et al. 2020).

In addition to the fact that a fair amount of urban pollinator-promoting interventions are understudied, pollinator groups are also not equally represented in the urban samplings. Based on the re-analytical data-synthesis of the urban topic, butterflies are the most studied pollinator group (i.e. 17 studies), while other flies (i.e. non-syrphid) and flower-visiting beetles are very rarely studied groups (i.e. 4 and 4 studies respectively). Non-syrphid flies and flower-visiting beetles can be important and sometimes exclusive pollinators for many plant species, but little is known about their role in the plant-pollinator systems (Orford et al. 2015; Muinde and Katumo 2024). For a long time, the importance of hoverflies was not well known, but nowadays this group is getting more and more attention (Vujić et al. 2022). However, much more attention should be paid to the other two mentioned pollinator groups, which probably need novel field sampling approaches. Another unanswered question is whether the urban pollinator-promoting interventions facilitate only common species or are beneficial for rare species as well (van Klink et al. 2023). It would be worth exploring this topic at synthesis-level in both agricultural and semi-natural areas. Nevertheless, our work in Task 4.2. draw attention to the importance of 'mowing out of farmlands' to promote pollinators. Beyond the details revealed here, it is essential to gather synthesis-level knowledge as quickly as possible about other anthropogenically converted, non-urban and non-agricultural areas, such as solar parks and power line corridors (Dániel-Ferreira et al. 2020).

Protected (incl. Natura 2000), natural and (semi-)natural areas, public spaces, and urban habitats need similar, but also different approaches. All pollinators in these habitats are under threat, as well the lack of baseline population data for most species and infrequent studies on the impact of management actions on pollinators contribute to the persistent unknowns in this field (Glenny et al. 2022). Based on the detailed review of (semi-)natural areas and public spaces in the USA by Glenny et al. (2022), the removal of invasive shrubs and the application of wildflower mixes consistently yielded positive outcomes for pollinators. However, grazing showed negative or neutral effects on pollinators depending on the study regions (Glenny et al. 2022). On the other hand, prescribed burning showed neutral or positive impacts on bees and negative impacts on butterflies, while logging exhibited neutral to positive effects across ecosystems and taxa (Glenny et al. 2022). Notably, the combination of burning and logging proved beneficial for pollinators, even when each practice alone showed no discernible effects (Glenny et al. 2022). However, on the European continent, different habitats and species occur, which need different conservation regimes (Lamers et al. 2015), so European-level case studies, reviews, meta-analyses, and data-driven syntheses of the pollinator-promoting interventions in protected areas are also needed. Compared to the many studies investigating prescribed burning in the USA (Glenny et al. 2022), none of the collected datasets from protected habitats addressed this intervention. Burning as a conservation practice is completely banned in some European countries, so this intervention is understudied and its impact is almost unknown (Valkó et al. 2014).

In protected areas, the habitat quality for pollinators can be efficiently improved by boosting food resources, where extensive mowing or grazing are widely used methods according to the gathered datasets (Sárospataki et al. 2009; Kőrösi et al. 2014). Mowing and grazing as a conservation practice had to be applied in some vegetation types to avoid scrub encroachment (Ernst et al. 2017; Mora et al. 2021), while in other habitat types (e.g. sub-alpine grasslands, sandpits, and reeds) abandonment was successfully used as a pollinator-promoting intervention (Zografou et al. 2009; Heneberg et al. 2013, 2017). On the other hand, the other intervention types such as flower sowing (i.e. overseeding) and mulching were hardly considered and studied in protected areas (Georgi et al. 2023). Flower sowing is perhaps a difficult intervention to establish in protected areas (i.e. 1 gathered dataset), because in many cases the legal issues are not clear, e.g. what seed mixtures can be used, from which distributor they should be obtained (Tinsley et al. 2006; Mainz and Wieden 2019; Müller et al. 2024). In addition to the fact that a fair amount of pollinator-promoting interventions in protected areas are understudied, vegetation types are also not equally represented in the samplings. Reeds also can be suitable nesting sites for cavity-nesting species but their potential is hardly known (Heneberg et al. 2017). In addition, forests are rarely surveyed (i.e. 4 gathered datasets) because they are not primary pollinator habitats but with intervention types such as gap creation and uprooting+girdling, forests can turn into suitable habitats for pollinators (Eckerter et al. 2021, 2022; Kozel et al. 2021). Different management and sampling methods may be needed in forests compared to grasslands, which can make it harder to establish and study pollinator-promoting interventions in forests. In addition, the types of protected areas themselves are not the same between continents and countries (European Commission 1992; Dudley 2008), while terms and concepts (such as public lands) are not always clearly defined (Glenny et al. 2022), thus the conservation actions and land management in these areas are difficult to assess. Nevertheless, even with the continuous gathering of pollinator data and collaboration with local authorities, there remains a deficiency in baseline data for several pollinator populations, while local authorities are uninformed about the impacts of their management actions on pollinators (Hanula et al. 2016; Woodard et al. 2020; Glenny et al. 2022). Synthesizing the influence of management actions on pollinators could aid local authorities in making decisions that align with the goals of pollinator conservation (Table 3).

Table 3. Take-home messages and considerations for different types of interventions.

Intervention type	Urban areas	Protected areas
abandonment	natural regeneration, but pay attention to invasive plant species	natural regeneration, but pay attention to scrub encroachment
bare ground surfaces	only beneficial for ground-nesting species, subsequently can be a weed and invasive hotspot due to inappropriate abandonment	
bee hotels and nesting boxes	only beneficial for cavity-nesting species, pay attention to invasive insect species	natural processes in nature should be supported, which naturally create these places
diversification of the vegetation structure	provide shelter and shade besides nectar and pollen, but pay attention to avoid planting invasive species	
extensive grazing	citizens may be disturbed by e.g. smell, possibly negative processes, coprophagous flies, the spread of disease	enable the development of flowers and seeds and increase plant species richness compared to intensive grazing
extensive mowing	enable the development of flowers and seeds and increase plant species richness, but could be improved with overseeding and mosaic or meandering mowing	
extensive mulching	prevent larval mortality and enable the development of flowers and seeds	
flower sowing	only native seed mixtures, aesthetic values, worth investigating how resilient they will be to climate change	only native seed mixtures, facilitate regeneration as overseeding
forest gap creation	not applicable	promote flowering herbaceous plants via increased sunlight exposure
green roofs, balconies, terraces	increase the proportion of urban green space	not applicable
low management intensity (as combined practices)	reduce the pressure by use of chemicals and management	
prescribed burning	not applicable	promote flowering herbaceous plants via new niches, control invasive species
uprooting and girdling	not applicable	increase aboveground-nesting sites, promote flowering plants via increased sunlight exposure

4.2. Effects of pollinator-promoting interventions in Hungary

Studying three different pollinator-promoting interventions in two Hungarian cities, we found that the less frequently mown public spaces had higher and greener vegetation with more flowers and pollinators than the frequently mown areas, in parallel with earlier studies (Garbuzov et al. 2015; Dylewski et al. 2019; Del Toro and Ribbons 2020; Horák et al. 2022). However, the found positive effect varies even within a season, e.g. the differences mostly disappeared by August. The sown flower patches provided food for many pollinators in the second half of the season, when food resources are insufficient in urban landscapes, such as dry or mown traditional parks and public spaces (Blackmore and Goulson 2014; Hicks et al. 2016; Norton et al. 2019; Mody et al. 2020; Dietzel et al. 2023). Compared to the extensively mown sites, here, the weed seedlings were eliminated annually in April with soil scarification and re-sowing in May. Hence these seedbeds with bare soil did not provide food, thus until the sown species bloomed, the conventionally managed sites were more beneficial for pollinators. Süle et al. (2023a) found almost neutral results on community composition and indicator pollinator guild analyses suggesting a homogenized urban pollinator community within the cities (Deguines et al. 2016). In contrast, any change in community composition can only be expected in the long term in the highly artificial urban environment. Any changes in the community composition will probably start in treatment sites close to semi-natural areas near the outskirts of the cities (Piano et al. 2019), so longer-term monitoring and spatio-temporal analysis are needed.

4.2.1. Temporal changes within seasons

The Hungarian case studies revealed temporal changes in floral resources and pollinators within the seasons are probably explained by the seasonality in plant-pollinator systems (Roulston and Goodell 2011; Thomas and Schultz 2016; Szigeti et al. 2018), the floral resource availability in the landscape (Timberlake et al. 2019), the climate of the year (Colom et al. 2021; ODWMS 2023), and the temporal aspects of the different managements (Wastian et al. 2016; Norton et al. 2019). Although the sown sites provided floral resources only in the second half of the season, Mix1 started to flower earlier (in June 2022), than Mix2, causing seasonal differences in floral resources and pollinator communities also among the sown sites (Süle et al. 2023a).

The studied different types of pollinator-promoting management methods may also complement each other side by side in cities, e.g. the two types of approaches (extensive mowing and sowing) in our case studies provided flower resources in the first half and the second half of the season respectively (Blackmore and Goulson 2014; Del Toro and Ribbons 2020). However, a mosaic mowing system alone would be a suitable solution to provide continuous food resources during the whole season while establishing more resilient vegetation even in drought conditions (Valtonen et al. 2006; O'Sullivan et al. 2017) as well as help to avoid the degradation of non-frequently mown urban green areas (O'Sullivan et al. 2017; Unterweger et al. 2018; Wintergerst et al. 2021).

4.2.2. Experiences from imperfect management

In the Hungarian case studies during the sampled years, the positive effect of the pollinator-promoting interventions was less than we expected. Imperfect management and extreme weather conditions may have caused this issue. The off-scheduled mowing and non-removed hay could have resulted in inhibited re-flowering, organic matter accumulation and desiccation causing potential long-term degradation (e.g. setting back the vegetation for several months; Noordijk et al. 2009; Manninen et al. 2010). In the case of sowing, too strong watering in the initial period and/or later the extreme drought probably damaged the seeds and sprouts of sown species. While in the same time, these conditions may have favoured the more resistant weeds. In addition, weeding seemed improperly carried out during the whole season, resulting in heavy weed infestation (pers. obs. and comm. with local authority). Both management inaccuracies could have contributed to the insufficient emergence/growth of sown species (Hitchmough et al. 2004).

Compared to some Western European examples (Noordijk et al. 2009; Hicks et al. 2016; Norton et al. 2019; Lange-Kabitz et al. 2021), in the post-Soviet, Eastern Europe countries, the urban pollinator-promoting interventions are still in their early stages. The lack of monitoring and the potential inaccuracies in the management of pollinator-promoting interventions are concerning issues (Noordijk et al. 2009; Hicks et al. 2016; Norton et al. 2019; Lange-Kabitz et al. 2021) and decreasing the potential efficiency of these interventions (Wilk et al. 2019). Therefore, promoting and monitoring such urban projects along with the involvement of the citizens could be appropriate for contributing to pollinator conservation also in Eastern European cities (European Commission 2023).

4.3. Urban pollinator-promoting interventions within Europe

Knowledge about the influence of local habitat management on urban biodiversity is crucial for the contribution to pollinator conservation in cities. Reduced mowing and sown flower patches have proven to be adequate pollinator-promoting interventions in the USA and Western Europe according to several case studies (Wastian et al. 2016; Norton et al. 2019). However, little is known so far about the effectiveness of any conservation practices in Eastern European urban areas as well as their synthesis level impacts. In our re-analytical data-synthesis and Hungarian case studies, we evaluated the effects of interventions on vegetation, pollinators, and floral resources. Especially in the Hungarian case studies, we monitored the whole season by five sampling occasions, providing novel insights into the fine-scale temporal dynamics of pollinator-promoting interventions, compared to previous studies mostly presenting only yearly pooled or summer-period results (Banaszak-Cibicka and Żmihorski 2020; Dylewski et al. 2020; Fournier et al. 2020).

4.3.1. Recommendations on pollinator promotion and monitoring

In the two sampled cities in Hungary, the local authorities used a broader set of biodiversity-supporting initiatives, such as environmental education programmes (e.g. citizens prepare bee hotels), installing bee hotels and birdhouses, continuously increasing the number of extensively mowed sites, and introducing community composting places (Hegyvidéki Önkormányzat 2020; Báthoryné et al. 2021; Takács 2021). These multiple interventions can support pollinators at several levels (Baldock 2020), but some aspects probably need re-consideration. For example, invasive species (e.g. *Erigeron annuus* (L.) Pers., *Solidago* sp.; Kovács-Hostyánszki et al. (2022)) potentially could spread in the extensively mown sites, which problem must be taken into account during designing the mowing schedule by avoiding the invaded areas' inclusion in pollinator-promoting projects until appropriate eradications (Jang et al. 2020). We also suggest careful consideration of the type of seed mixture used for sowing (Hicks et al. 2016). In our case study, Mix 2 contained a higher proportion of non-native *Asterales* species, blooming in late summer (Süle et al. 2023b), limiting the pollinator species that could forage on these plots (Ballantyne et al. 2017). In contrast, Mix 1, the mainly native mixture of annual and perennial species with different floral morphologies provided a longer flowering period from June and probably offered less food while for more pollinator species by their diverse floral traits (Salisbury et al. 2015). Seed mixes containing non-native plants pose a potential risk to urban green spaces, as well as semi-natural and protected areas in the neighbourhood (Tinsley et al. 2006; Kandori et al. 2009; Süle et al. 2023b). It would be crucial to ban the planting of invasive herbaceous species in public spaces and gardens (e.g. *Solidago* spp., *Aster* spp., *Gaillardia* spp.; Süle et al. (2023b)), use only native seed mixtures (Wilk et al. 2019), which even lack standard regulation in Hungary, the EU or worldwide (Tinsley et al. 2006; Mainz and Wieden 2019). However, we can find nice examples from

Germany regarding native seed mixture legalisation (Mainz and Wieden 2019), but its utilisation is not mandatory leading to the use of easily accessible non-native mixtures. Companies producing native, region-specific, and local seeds should be strongly supported by actions and funding (Müller et al. 2024). Meanwhile, new regulations should be introduced, because there is already a demand for native seed mixtures and nature restoration (Council of the EU 2023; Müller et al. 2024), but (local/native-)seed suppliers are lacking in most regions. Based on our opinion, the native seed mixture should contain a higher proportion of perennial species, facilitating the long-term establishment of sown areas without annual soil disturbance, which could also reduce the costs (Norton et al. 2019) and increase the benefits for ground-nesting bees, overwintering pollinators, and herbivore larvae using the sown species as hostplants (Unterweger et al. 2018; Lange-Kabitz et al. 2021). To improve the quality of floral resources for years with minimal soil disturbance, the best option would be to combine the two types of interventions such as overseeding the green areas with native seed mixture and maintaining them with a mosaic mowing system (Ferreira et al. 2011; Neumüller et al. 2021). Also, note that the timing, ratio, and location of the mown area should be determined site-specifically according to the local environmental and societal conditions.

Based on the re-analytical data-synthesis and the Hungarian case studies, the pollinator-promoting practices had a significant positive effect on pollinators. However, the sampled cities within Europe may differ from each other in several socio-ecological attributes, which should be considered. Hence, we need further studies from more and more cities to explore in detail, whether the pollinator-promoting management methods would be also effective and beneficial on a wider spatio-temporal scale (Keilsohn et al. 2018). For example, how much the effectiveness of interventions depends on the correspondence with landscape-scale factors such as the proportion of green infrastructures (Dylewski et al. 2020; Prendergast et al. 2022). Nevertheless, to appropriately reveal these interventions could be a successful contribution to pollinator conservation, i.e. no sink habitats were created (Gardiner et al. 2018), long-term monitoring is needed on vegetation attributes, floral resources, pollinators, nesting sites and even co-benefits of these projects such as microclimatic conditions, soil regeneration, and aesthetic values (Norton et al. 2019). Also, to reveal the details in pollinator communities, i.e. which pollinator species prefer or avoid the treatment sites, there is a need for novel, low-impact urban trapping and capturing approaches. Urban habitats may require different sampling methods compared to semi-natural areas, while there are different types of habitats within cities (e.g. public parks, road verges, and private gardens) where the same sampling methods can not be used (Tremblay and Underwood 2023). As well, the different sampling methods can often lead to different results due to the target group, catching success, and habitat type (Scherber et al. 2019; Thompson et al. 2021). These aspects also show that there are many questions to be studied here, starting from what are the best sampling methods in specific habitat types. In urban settings, ethical considerations also need to be taken into account in terms of the citizens's perception of lethal and non-lethal sampling methods (Lövei and Ferrante 2024).

Besides ecological impact, societal aspects of pollinator-promoting interventions should also be taken into account (Southon et al. 2017). Although the reduced mowing benefits pollinators, it may lead to some undesirable negative consequences such as the increase of garbage in tall grass because litter probably will be disposed more likely by citizens here, while noticed less by city workers, degrading these sites in long-term (Turo and Gardiner 2019). Unfortunately, negative attitudes from citizens in addition to some political repercussions toward the extensive mowing intervention could be encountered in Hungary (Balázsi 2021). Part of the citizens could be averse to higher vegetation due to untidy appearance, a presumed infestation of ticks, spikelets of *Hordeum murinum* L. (causing inflammation in dogs), and alien species triggering allergies (e.g. *Ambrosia artemisiifolia* L.), besides fearing of stings of wasp and bees. All of these factors in local circumstances should be revealed and studied for new types of green space interventions. In contrast, the urban pollinator-promoting interventions are mostly supported by the citizens in Western Europe (Southon et al. 2017).

For the Hungarian urban pollinator-promoting interventions, we tried to establish and maintain a system for the long term, where we present suggestions and opinions through a feedback system to the local authorities and municipalities, i.e. to important stakeholders. Based on our feedback, the interventions are adjusted and improved, e.g. eradication of *Hordeum murinum* (causing inflammation in dogs) and *Ambrosia artemisiifolia* (triggering allergies) and further invasive plant species, introduction of new sites, and seed mixture change from 2022 to 2023 (locally adapted native seed mixtures for long-term and sustainable use). Besides, we attach great importance to providing citizens with accurate and objective information on local urban pollinator-promoting interventions, so we conduct several presentations and media interviews regarding this topic (see Chapter 6).

5. Conclusions

Pollinator-promoting interventions, that have been applied previously in Western cities require specified modifications according to the local conditions of other regions, due to the contrasting socio-economic and ecological contexts (Batáry et al. 2010; Kronenberg 2015; Southon et al. 2017). Monitoring programmes should be established and improved, and their funding has to be secured in the long term, especially in less-developed more biodiverse locations. It is already clear from the urban re-analytical data-synthesis, that non-syrphid flies and flower-visiting beetles are underrepresented. Similarly, just a few surveys cover many habitat types. As well several pollinator-promoting interventions have not been studied in detail, while multiple interventions are not studied at all. In protected areas, we know little about the ecological processes of management effects, due to a strong trust or belief that the management of protected areas is appropriate. However, this is rarely evidenced by scientific research, while the importance of these areas for biodiversity and conservation is outstanding. We expect that a thorough, detailed evaluation of the re-analytical data-synthesis about protected areas will provide a solid scientific basis for taking a major step forward in the conservation of pollinators in all habitats. In protected areas, extensive mowing or grazing and abandonment are widely used methods, but flower sowing and mulching were hardly considered, while the impact of prescribed burning is almost unknown in Europe. In addition, vegetation types are also not equally represented because reeds as nesting sites are hardly considered and forests were also rarely surveyed.

Our simple sampling method in the Hungarian case studies could be suitable for use as a citizen-science approach that developed into a mobile sampling application offering personalised, ecological, and gamified experiences for citizens (sensu Soga and Gaston 2022). Meanwhile, there is considerable demand by stakeholders and local authorities for detailed recommendations (Wilk et al. 2019; NBDC 2020), as we provided above. However, broader datasets are needed to strengthen the general, as well as region-specific measures by evidence. During the maintenance of urban pollinator-promoting interventions, it is essential to pay attention to education and present up-to-date, transparent, interactive information for citizens about management while also gathering their opinions and feedback (Hall and Martins 2020). Interventions should be designed in a resilient way, e.g. using native, drought-resistant plant species and mosaic mowing regime, to be prepared for increasingly frequent extreme weather events such as droughts, due to climate change (Jentsch et al. 2007).

Our proposed synthesis papers on urban and protected pollinator-promoting interventions will provide more scientific, peer-reviewed results and recommendations, for which we have great expectations. However, both topics could benefit from dedicated scientific proposals on the development of pollinator monitoring (e.g. SPRING project; UFZ (2024)), as well dedicated grants extend and elaborate questions about pollinator promotions at urban and protected areas could be a big step forward.

6. Disseminations and publications for Task 4.2

6.1. Scientific publications and conferences

Süle, G., Kovács-Hostyánszki, A., Sárospataki, M., Kelemen, T.I., Halassy, G., Horváth, A., Demeter, I., Báldi, A., Szigeti, V. (2023). First steps of pollinator-promoting interventions in Eastern European urban areas – positive outcomes, challenges, and recommendations. *Urban Ecosystems*. 26. 1783–1797. https://doi.org/10.1007/s11252-023-01420-1

Süle, G., Kovács Hostyánszki, A., Kelemen, T.I., Horváth, A., Bakonyi, P., Kovács, O., Bajor, Z., Báldi, A., Szigeti, V. (2022). Safeguarding pollinators: creating urban bee pastures by extensive mowing benefits pollinators and wildflowers. *7th Student Conference on Conservation Science*, Balatonvilágos.

Kovács-Hostyánszki, A (2023). Bepozóbarát városok - a beporzó rovarok támogatásának lehetőségei települési környezetben (Pollinator-friendly cities - options for supporting pollinating insects in the urban environment). ELKH Ökológiai Kutatóközpont. 56. pp. https://ecolres.hu/wp-content/uploads/2023/03/Beporzo-barat-varosok-online-0313.pdf

Süle, G., Kovács Hostyánszki, A., Kelemen, T.I., Horváth, A., Demeter, I., Báldi, A., Szigeti, V. (2023). The effect of rare mowing and flower sowing on pollinators and wildflowers in public spaces. *4th International Conference on Community Ecology*, Trieste.

Süle, G., Németh, V., Báldi, A., Szigeti, V. (submitted abstract at *7th European Congress of Conservation Biology*): Starting-year effects of annual and perennial urban flower sowings on pollinators and floral resources.

Süle, G. et al. (manuscript under preparation): Moving out of the farmland: making urban areas more valuable for pollinators - a European-level re-analytical data-synthesis.

Süle, G. et al. (manuscript under preparation): Can protected area management reverse pollinators decline? - a European-level re-analytical data-synthesis.

6.2. Media appearances

Article on Wildflower Budapest 2021 Programme: the experiences of the first year of the programme (presenting the result of the Hungarian case study). 'Vadvirágos Budapest 2021: az első év eredményei és tapasztalatai'. https://budapest.hu/Lapok/2022/vadviragos-budapest-eredmenyek.aspx

Anikó Kovács-Hostyánszki's public presentation at the municipality of Budapest, 12th district (2023). The magical world of pollinators around us (including the result of the Hungarian case study). 'A körülöttünk élő beporzók varázslatos világa'. https://www.youtube.com/watch?v=eHvDiT-5Zj0

Article on Wildflower Budapest 2022 Programme: the experiences of the second year of the programme (presenting the result of the Hungarian case study). 'Vadvirágos Budapest 2022: a program második évének tapasztalatai'. https://budapest.hu/Lapok/2023/vadviragos-budapest-2022-a-program-masodik-evenek-tapasztalatai.aspx

Article on the urban pollinator-promoting interventions in Hungary with ca. ten thousand access by one of the leading news portals in Hungary: Finding out how urban beepastures are succeeding. 'Kiderült, hogyan válnak be a városi méhlegelők'. https://24.hu/tudomany/2023/09/04/mehlegelo-varosi-park-beporzok-okologia-kaszalas/

Radio interview on the urban pollinator-promoting interventions in Hungary: Beepastures have achieved positive changes from an ecological point of view. 'Ökológiai szempontból pozitív változásokat eredményeztek a méhlegelők'. http://xn--spirit%20fm%20-%20kolgiai%20szempontbl%20pozitv%20vltozsokat%20eredmnyeztek%20a%20mhlegelk,%20mondta%20szigeti%20viktor%20-%202023-09-05-f5ke93ipa73cu0aqa52bn65b/

Radio interview on the urban pollinator-promoting interventions in Hungary: Green club: efficiency of beepastures in the study sites in Budapest and Veszprém. 'Zöld klub:

méhlegelők hatékonysága budapesti és veszprémi mintaterületeken’. https://www.klubradio.hu/archivum/zoldklub-2023-szeptember-14-csutortok-1400-35684

Article on the urban pollinator-promoting interventions in Hungary: More flowers, more pollinators – The second year of wildflower meadows in Budapest. ‘Több virág, több beporzó – Ilyen volt a vadvirágos budapesti rétek második éve’. https://www.turistamagazin.hu/hir/tobb-virag-tobb-beporzo-a-vadviragos-budapesti-reteket-vizsgaltak

Viktor Szigeti's public presentation at the municipality of Budapest, 12th district (2024). Urban beepastures in focus: plant-pollinator relationships (including the result of the Hungarian case study). ‘Fókuszban a városi méhlegelők: növény-beporzó kapcsolatok.’ https://youtu.be/yn189XucF-o

7. Acknowledgements

7.1. Re-analytical data-synthesis

We are grateful to Dóra Teplánszki and Fruzsina Kőhalmi for their help in data sorting, and Zoltán Botta-Dukát for his help with statistical analysis. We are grateful to the following persons for providing us with datasets:

- Urban topic: Weronika Banaszak-Cibicka, Oliver Betz, Jovana Bila-Dubaić, Lorna M. Blackmore, Aleksandar Ćetković, Lorna J. Cole, Simon Dietzel, Łukasz Dylewski, Benoît Fontaine, Bertrand Fournier, Costanza Geppert, Dave Goulson, Janine Griffiths-Lee, Catriona Hawthorn, Andrea Holzschuh, Jakub Horák, Svenja Horstmann, Helen Hoyle, Vassiliki Kati, David Klein, Anikó Kovács-Hostyánszki, Carita Kuparinen, Lorenzo Marini, Alice Michelot-Antalik, Marco Moretti, Audrey Muratet, Briony Norton, Erik Öckinger, Benjamin B. Phillips, Milan Plećaš, Patrik Rada, Paula Salonen, Miklós Sárospataki, Sonja Schulze, Assaf Shwartz, Ingolf Steffan-Dewenter, Jenny Teerikangas, Olga Tzortzakaki, Philipp Unterweger, Stephen Venn.
- Protected topic: Matthias Albrecht, Péter Batáry, Carolin Biegerl, Veronika Braunisch, Jörn Buse, Andree Cappellari, Tristan Eckerter, Lunja Ernst, Thomas Fartmann, Florian Fumy, Michael Garratt, Maria Georgi, Elia Guariento, Petr Heneberg, Andreas Hilpold, Andrea Holzschuh, Sebastian Hopfenmüller, Jakub Horák, Raja Imran Hussain, Vassiliki Kati, Alexandra Maria Klein, Bence Kovács, Petr Kozel, Ádám Kőrösi, Egle Liiskmann, Franz Löffler, Lorenzo Marini, Gabrielle McLaughlin, Amparo Mora, Morgan Morrison, Konstantina Nasiou, Kriytýna Nehybová, Péter Ódor, Dominik Poniatowski, Zoltán Soltész, István Szentirmai, Csaba Tölgyesi, Dina Zografou.

7.2. Urban case studies

We are grateful to Ildikó Báthoryné Nagy (Hungarian University of Agriculture and Life Sciences); the Veszprém Public Utility Services, especially Kata Pernesz; the Green Office of Municipality of the 12th District in Budapest, especially Nóra Laki; the Horticultural Division of Budapest Public Utilities and the Municipality of Budapest, especially Orsolya Kovács managed the setting up of these pollinator-promoting interventions, and enabled and facilitated our samplings. We are grateful to Péter Bakonyi, Zsófia Gábor, Borbála Grób, Gabriella Halassy, Csaba Hegedűs, Anna Horváth, Tünde Ilona Kelemen, Anikó Kovács-Hostyánszki, Tímea Németh, Virág Németh, Raul Pellaton, Miklós Sárospataki, and Flóra Vajna for their help in fieldwork. We are grateful to receive funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003476 (www.safeguard.biozentrum.uni-wuerzburg.de).

8. References

Albrecht M, Kleijn D, Williams NM, et al (2020) The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis. Ecol Lett 23:1488–1498. https://doi.org/10.1111/ele.13576

Andy Bunn MK (2017) A language and environment for statistical computing. R Found. Stat. Comput. 10:11–18

Balázsi L (2021) Index: Lekaszálta a méhlegelőt a Fidelitas. https://index.hu/belfold/2021/06/28/mehelegelo-fidelitas-kormany-fovarosi-onkormanyzat-lekaszalas-karacsony-gergely-bardoczi-sandor/. Accessed 1 Apr 2023

Báldi A, Batáry P, Kleijn D (2013) Effects of grazing and biogeographic regions on grassland biodiversity in Hungary - analysing assemblages of 1200 species. Agric Ecosyst Environ 166:28–34. https://doi.org/10.1016/j.agee.2012.03.005

Báldi A, Pellaton R, Bihaly ÁD, et al (2022) Improving ecosystem services in farmlands: beginning of a long-term ecological study with restored flower-rich grasslands. Ecosyst Heal Sustain 8:1–7. https://doi.org/10.1080/20964129.2022.2090449

Baldock KCR (2020) Opportunities and threats for pollinator conservation in global towns and cities. Curr Opin Insect Sci 38:63–71. https://doi.org/10.1016/j.cois.2020.01.006

Baldock KCR, Goddard MA, Hicks DM, et al (2019) A systems approach reveals urban pollinator hotspots and conservation opportunities. Nat Ecol Evol 3:363–373. https://doi.org/10.1038/s41559-018-0769-y

Ballantyne G, Baldock KCR, Rendell L, Willmer PG (2017) Pollinator importance networks illustrate the crucial value of bees in a highly speciose plant community. Sci Rep 7:1–13. https://doi.org/10.1038/s41598-017-08798-x

Banaszak-Cibicka W, Żmihorski M (2020) Are cities hotspots for bees? Local and regional diversity patterns lead to different conclusions. Urban Ecosyst 23:713–722. https://doi.org/10.1007/s11252-020-00972-w

Barton K (2023) Package ‘ MuMIn ’ Multi-Model Interface

Batáry P, Báldi A, Sárospataki M, et al (2010) Effect of conservation management on bees and insect-pollinated grassland plant communities in three European countries. Agric Ecosyst Environ 136:35–39. https://doi.org/10.1016/j.agee.2009.11.004

Báthoryné NIR, Gergely A, Pernesz K, et al (2021) Klímaadaptív gyepgazdálkodás a városban. VKSZ Veszprémi Közüzemi Szolgáltató Zrt., Szent István Egyetem, Veszprém

Ben-Ari T (2023) How research can steer academia towards a low-carbon future. Nat Rev Phys 5:551–552. https://doi.org/10.1038/s42254-023-00633-9

Benes J, Cizek O, Dovala J, Konvicka M (2006) Intensive game keeping, coppicing and butterflies: The story of Milovicky Wood, Czech Republic. For Ecol Manage 237:353–365. https://doi.org/10.1016/j.foreco.2006.09.058

Bivand R, Altman M, Anselin L, et al (2015) Package ‘spdep’. Spatial Dependence: Weighting Schemes, Statistics and Models.

Blackmore LM, Goulson D (2014) Evaluating the effectiveness of wildflower seed mixes for boosting floral diversity and bumblebee and hoverfly abundance in urban areas. Insect Conserv Divers 7:480–484. https://doi.org/10.1111/icad.12071

Bommarco R, Kleijn D, Potts SG (2013) Ecological intensification: Harnessing ecosystem services for food security. Trends Ecol Evol 28:230–238.

https://doi.org/10.1016/j.tree.2012.10.012

Braaker S, Obrist MK, Ghazoul J, Moretti M (2017) Habitat connectivity and local conditions shape taxonomic and functional diversity of arthropods on green roofs. J Anim Ecol 86:521–531. https://doi.org/10.1111/1365-2656.12648

Braman SK, Griffin B (2022) Opportunities for and Impediments to Pollinator Conservation in Urban Settings: A Review. J Integr Pest Manag 13:. https://doi.org/10.1093/jipm/pmac004

Brooks ME, Kristensen K, van Benthem KJ, et al (2017) glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. R J 9:378–400. https://doi.org/10.32614/rj-2017-066

Carrié R, Ekroos J, Smith HG (2018) Organic farming supports spatiotemporal stability in species richness of bumblebees and butterflies. Biol Conserv 227:48–55. https://doi.org/10.1016/j.biocon.2018.08.022

Colom P, Traveset A, Carreras D, Stefanescu C (2021) Spatio-temporal responses of butterflies to global warming on a Mediterranean island over two decades. Ecol Entomol 262–272. https://doi.org/10.1111/een.12958

Corbet SA, Williams IH, Osborne JL (1991) Bees and the Pollination of Crops and Wild Flowers in the European Community. Bee World 72:47–59. https://doi.org/10.1080/0005772X.1991.11099079

Council of the EU (2023) Nature restoration: Council and Parliament reach agreement on new rules to restore and preserve degraded habitats in the EU. Press release

Dániel-Ferreira J, Bommarco R, Wissman J, Öckinger E (2020) Linear infrastructure habitats increase landscape-scale diversity of plants but not of flower-visiting insects. Sci Rep 10:1–11. https://doi.org/10.1038/s41598-020-78090-y

DEFRA (2014) The National Pollinator Strategy: for bees and other pollinators in England

Deguines N, Julliard R, de Flores M, Fontaine C (2016) Functional homogenization of flower visitor communities with urbanization. Ecol Evol 6:1967–1976. https://doi.org/10.1002/ece3.2009

Del Toro I, Ribbons RR (2020) No Mow May lawns have higher pollinator richness and abundances: An engaged community provides floral resources for pollinators. PeerJ 8:1–16. https://doi.org/10.7717/peerj.10021

Dietzel S, Rojas-Botero S, Kollmann J, Fischer C (2023) Enhanced urban roadside vegetation increases pollinator abundance whereas landscape characteristics drive pollination. Ecol Indic 147:109980. https://doi.org/10.1016/j.ecolind.2023.109980

Domroese MC, Johnson EA (2017) Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. Biol Conserv 208:40–47. https://doi.org/10.1016/j.biocon.2016.08.020

Dudley N (2008) Guidelines for Applying Protected Area Management Categories. IUCN, Gland, Switzerland

Duflot R, Fahrig L, Mönkkönen M (2022) Management diversity begets biodiversity in production forest landscapes. Biol Conserv 268:. https://doi.org/10.1016/j.biocon.2022.109514

Dylewski Ł, Maćkowiak Ł, Banaszak-Cibicka W (2019) Are all urban green spaces a favourable habitat for pollinator communities? Bees, butterflies and hoverflies in different urban green areas. Ecol Entomol 44:678–689. https://doi.org/10.1111/een.12744

Dylewski Ł, Maćkowiak Ł, Banaszak-Cibicka W (2020) Linking pollinators and city flora: How vegetation composition and environmental features shapes pollinators composition in urban environment. Urban For Urban Green 56:126795. https://doi.org/10.1016/j.ufug.2020.126795

ECA (2020) Protection of wild pollinators in the EU — Commission initiatives have not borne fruit

Eckerter T, Braunisch V, Buse J, Klein AM (2022) Open forest successional stages and landscape heterogeneity promote wild bee diversity in temperate forests. Conserv Sci Pract 4:e12843. https://doi.org/10.1111/csp2.12843

Eckerter T, Buse J, Bauhus J, et al (2021) Wild bees benefit from structural complexity enhancement in a forest restoration experiment. For Ecol Manage 496:119412. https://doi.org/10.1016/j.foreco.2021.119412

Ernst LM, Tscharntke T, Batáry P (2017) Grassland management in agricultural vs . forested landscapes drives butter fl y and bird diversity. Biol Conserv 216:51–59. https://doi.org/10.1016/j.biocon.2017.09.027

European Commission (1992) Conservation of NaturalHabitats and of Wild Fauna and Flora. Brüssel

European Commission (2023) Revision of the EU Pollinators Initiative

Ferreira ET, Nabinger C, Adelaide D, et al (2011) Fertilization and oversowing on natural grassland : effects on pasture characteristics and yearling steers performance. Rev Bras Zootec 40:2039–2047. https://doi.org/http://dx.doi.org/10.1590/S1516-35982011000900028

Fiala K, Barta K, Benyhe B, et al (2018) Operatív aszály- és vízhiánykezelő monitoring rendszer. Hidrológiai Közlöny 98.:14-24.

flower your place (2023) Aurora. https://floweryourplace.com/product/aurora/. Accessed 1 Apr 2023

Fortel L, Henry M, Guilbaud L, et al (2016) Use of human-made nesting structures by wild bees in an urban environment. J Insect Conserv 20:239–253. https://doi.org/10.1007/s10841-016-9857-y

Foster G, Bennett J, Sparks T (2017) An assessment of bumblebee (Bombus spp) land use and floral preference in UK gardens and allotments cultivated for food. Urban Ecosyst 20:425–434. https://doi.org/10.1007/s11252-016-0604-7

Fournier B, Frey D, Moretti M (2020) The origin of urban communities: From the regional species pool to community assemblages in city. J Biogeogr 47:615–629. https://doi.org/10.1111/jbi.13772

Garbuzov M, Fensome KA, Ratnieks FLW (2015) Public approval plus more wildlife: Twin benefits of reduced mowing of amenity grass in a suburban public park in Saltdean, UK. Insect Conserv Divers 8:107–119. https://doi.org/10.1111/icad.12085

Gardiner MM, Riley CB, Bommarco R, Öckinger E (2018) Rights-of-way: a potential conservation resource. Front Ecol Environ 16:149–158. https://doi.org/10.1002/fee.1778

Gaston KJ, Jackson SF, Cantú-Salazar L, Cruz-Piñón G (2008) The ecological performance of protected areas. Annu Rev Ecol Evol Syst 39:93–113. https://doi.org/10.1146/annurev.ecolsys.39.110707.173529

Gavrilidis AA, Popa AM, Nita MR, et al (2020) Planning the “unknown”: Perception of urban green infrastructure concept in Romania. Urban For Urban Green 51:126649. https://doi.org/10.1016/j.ufug.2020.126649

Georgi MM, Gärtner SM, Förschler MI, et al (2023) Mulching time of forest meadows influences insect diversity. Insect Conserv Divers 1–11. https://doi.org/10.1111/icad.12629

Glenny W, Runyon JB, Burkle LA (2022) A review of management actions on insect pollinators on public lands in the United States. Biodivers Conserv 31:1995–2016. https://doi.org/10.1007/s10531-022-02399-5

Gohin A, Zheng Y (2020) Reforming the European Common Agricultural Policy: From price & income support to risk management. J Policy Model 42:712–727. https://doi.org/10.1016/j.jpolmod.2020.02.008

Goulson D, Nicholls E, Botías C, Rotheray EL (2015) Bee declines driven by combined Stress from parasites, pesticides, and lack of flowers. Science (80-) 347:. https://doi.org/10.1126/science.1255957

Griffiths-Lee J, Nicholls E, Goulson D (2022) Sown mini-meadows increase pollinator diversity in gardens. J Insect Conserv 26:299–314. https://doi.org/10.1007/s10841-022-00387-2

Gurevitch J, Koricheva J, Nakagawa S, Stewart G (2018) Meta-analysis and the science of research synthesis. Nature 555:175–182. https://doi.org/10.1038/nature25753

Guzman LM, Chamberlain SA, Elle E (2021) Network robustness and structure depend on the phenological characteristics of plants and pollinators. Ecol Evol 11:13321–13334. https://doi.org/10.1002/ece3.8055

Hall DM, Martins DJ (2020) Human dimensions of insect pollinator conservation. Curr Opin Insect Sci 38:107–114. https://doi.org/10.1016/j.cois.2020.04.001

Hanula JL, Ulyshen MD, Horn S (2016) Conserving Pollinators in North American Forests: A Review. Nat Areas J 36:427–439. https://doi.org/10.3375/043.036.0409

Hegyvidéki Önkormányzat (2020) VADVIRÁGOS LEGELŐK A HEGYVIDÉKI MÉHEKNEK. https://www.hegyvidekujsag.hu/archivum/archivum-2020-januar-28/vadviragos-legelok. Accessed 1 Apr 2022

Heneberg P, Bogusch P, Řehounek J (2013) Sandpits provide critical refuge for bees and wasps (Hymenoptera: Apocrita). J Insect Conserv 17:473–490. https://doi.org/10.1007/s10841-012-9529-5

Heneberg P, Bogusch P, Tauchmanová P, et al (2017) Common reed (Phragmites australis) gall as the limiting nesting resource of rare wetland bees and wasps (Hymenoptera: Aculeata & Evanioidea) in Central Europe. Ecol Eng 108:100–113. https://doi.org/10.1016/j.ecoleng.2017.08.014

Hicks DM, Ouvrard P, Baldock KCR, et al (2016) Food for pollinators: Quantifying the nectar and pollen resources of urban flower meadows. PLoS One 11:1–37. https://doi.org/10.1371/journal.pone.0158117

Hinners SJ, Kearns CA, Wessman CA (2012) Roles of scale, matrix, and native habitat in supporting a diverse suburban pollinator assemblage. Ecol Appl 22:1923–1935. https://doi.org/10.1890/11-1590.1

Hitchmough J, De La Fleur M, Findlay C (2004) Establishing North American prairie vegetation in urban parks in northern England: Part 1. Effect of sowing season, sowing rate and soil type. Landsc Urban Plan 66:75–90. https://doi.org/10.1016/S0169-2046(03)00096-3

Hopfenmüller S, Holzschuh A, Steffan-Dewenter I (2020) Effects of grazing intensity, habitat area and connectivity on snail-shell nesting bees. Biol Conserv 242:. https://doi.org/10.1016/j.biocon.2020.108406

Horák J, Šafářová L, Trombik J, Menéndez R (2022) Patterns and determinants of plant, butterfly and beetle diversity reveal optimal city grassland management and green urban planning. Urban For Urban Green 73:0–3. https://doi.org/10.1016/j.ufug.2022.127609

Hoyle H, Jorgensen A, Warren P, et al (2017) “Not in their front yard” The opportunities and challenges of introducing perennial urban meadows: A local authority stakeholder perspective. Urban For Urban Green 25:139–149. https://doi.org/10.1016/j.ufug.2017.05.009

HungaroMet (2024) 2023 a legmelegebb és a nyolcadik legcsapadékosabb év 1901 óta – előzetes elemzés. https://www.met.hu/rolunk/hirek/index.php?id=3395&hir=2023_a_legmelegebb_es_a_n y olcadik_legcsapadekosabb_ev_1901_ota_–_elozetes_elemzes. Accessed 22 Jan 2024

IPBES (2016) The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany

Jang W, Eskelson BNI, Murray T, et al (2020) Relationships between invasive plant species occurrence and socio-economic variables in urban green spaces of southwestern British Columbia, Canada. Urban For Urban Green 47:126527. https://doi.org/10.1016/j.ufug.2019.126527

Jenks M, Jones C (2010) Dimensions of the Sustainable City. Speinger

Jentsch A, Kreyling J, Beierkuhnlein C (2007) A new generation of climate-change experiments: events, not trends. Front Ecol Environ 5:365–374. https://doi.org/https://doi.org/10.1890/1540-9295(2007)5[365:ANGOCE]2.0.CO;2

Kabisch N, Haase D (2013) Green spaces of European cities revisited for 1990-2006. Landsc Urban Plan 110:113–122. https://doi.org/10.1016/j.landurbplan.2012.10.017

Kandori I, Hirao T, Matsunaga S, Kurosaki T (2009) An invasive dandelion unilaterally reduces the reproduction of a native congener through competition for pollination. Oecologia 159:559–569. https://doi.org/10.1007/s00442-008-1250-4

Keilsohn W, Narango DL, Tallamy DW (2018) Roadside habitat impacts insect traffic mortality. J Insect Conserv 22:183–188. https://doi.org/10.1007/s10841-018-0051-2

Kleijn D, Winfree R, Bartomeus I, et al (2015) Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nat Commun 6:. https://doi.org/10.1038/ncomms8414

Konvicka M, Kadlec T (2011) How to increase the value of urban areas for butterfly conservation? A lesson from Prague nature reserves and parks. Eur J Entomol 108:219–229. https://doi.org/10.14411/eje.2011.030

Kőrösi Á, Szentirmai I, Batáry P, et al (2014) Effects of timing and frequency of mowing on the threatened scarce large blue butterfly - A fine-scale experiment. Agric Ecosyst Environ 196:24–33. https://doi.org/10.1016/j.agee.2014.06.019

Kovács-Hostyánszki A, Espíndola A, Vanbergen AJ, et al (2017) Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. Ecol Lett 20:673–689. https://doi.org/10.1111/ele.12762

Kovács-Hostyánszki A, Földesi R, Mózes E, et al (2016) Conservation of Pollinators in Traditional Agricultural Landscapes - New Challenges in Transylvania (Romania) Posed by EU Accession and Recommendations for Future Research. PLoS One 11:1–20. https://doi.org/10.1371/journal.pone.0151650

Kovács-Hostyánszki A, Soltész Z, Szigeti V, et al (2021) Non-rotational set-aside fields improve reproductive success of cavity-nesting bees and wasps at the landscape scale, but have no effect on other wild bees and hoverflies in mid-summer. Agric Ecosyst Environ 308:. https://doi.org/10.1016/j.agee.2020.107255

Kovács-Hostyánszki A, Szigeti V, Miholcsa Z, et al (2022) Threats and benefits of invasive alien plant species on pollinators. Manuscr Submitt Publ

Kovács O, Bajor Z, Szigeti V, et al (2021) A budapesti "méhlegelők" monitoringja - az első év tapasztalatai. In: 2. Urbanizációs Ökológia Konferencia. 2021. 10. 14-15. Győr, p 48

Kozel P, Sebek P, Platek M, et al (2021) Connectivity and succession of open structures as a key to sustaining light-demanding biodiversity in deciduous forests. J Appl Ecol 58:2951–2961. https://doi.org/10.1111/1365-2664.14019

Kronenberg J (2015) Why not to green a city? Institutional barriers to preserving urban ecosystem services. Ecosyst Serv 12:218–227. https://doi.org/10.1016/j.ecoser.2014.07.002

KSH (2022) 15.1.1.37. Magyarország és Budapest időjárásának adatai. https://www.ksh.hu/stadat_files/kor/hu/kor0037.html. Accessed 1 Apr 2023

Kubinec R (2023) Ordered Beta Regression: A Parsimonious, Well-Fitting Model for Continuous Data with Lower and Upper Bounds. Polit Anal 31:519–536. https://doi.org/10.1017/pan.2022.20

Lamers LPM, Vile MA, Grootjans AP, et al (2015) Ecological restoration of rich fens in Europe and North America: from trial and error to an evidence-based approach. Biol Rev Camb Philos Soc 90:182–203. https://doi.org/10.1111/brv.12102

Lange-Kabitz C, Reich M, Zoch A (2021) Extensively managed or abandoned urban green spaces and their habitat potential for butterflies. Basic Appl Ecol 54:85–97. https://doi.org/10.1016/j.baae.2021.04.012

Lerman SB, Contosta AR, Milam J, Bang C (2018) To mow or to mow less: Lawn mowing frequency affects bee abundance and diversity in suburban yards. Biol Conserv 221:160–174. https://doi.org/10.1016/j.biocon.2018.01.025

Leverington F, Costa KL, Pavese H, et al (2010) A global analysis of protected area management effectiveness. Environ Manage 46:685–698. https://doi.org/10.1007/s00267-010-9564-5

Liang H, He Y, Theodorou P, Yang C (2023) The effects of urbanization on pollinators and pollination: A meta-analysis. Ecol Lett 26:1629–1642. https://doi.org/10.1111/ele.14277

Lövei GL, Ferrante M (2024) The Use and Prospects of Nonlethal Methods in Entomology. Annu Rev Entomol 69:. https://doi.org/10.1146/annurev-ento-120220-024402

Mach BM, Potter DA (2018) Quantifying bee assemblages and attractiveness of flowering woody landscape plants for urban pollinator conservation. PLoS One 13:1–18. https://doi.org/10.1371/journal.pone.0208428

Mainz AK, Wieden M (2019) Ten years of native seed certification in Germany – a summary. Plant Biol 21:383–388. https://doi.org/10.1111/plb.12866

Majewska AA, Altizer S (2020) Planting gardens to support insect pollinators. Conserv Biol 34:15–25. https://doi.org/10.1111/cobi.13271

Manninen S, Forss S, Venn S (2010) Management mitigates the impact of urbanization on meadow vegetation. Urban Ecosyst 13:461–481. https://doi.org/10.1007/s11252-010-0129-4

Marshall EJP (2005) Field margins in northern Europe: Integrating agricultural, environmental and biodiversity functions. In: Thomas AG (ed) Topics in Canadian Weed Science. FieldBoundary Habitat: Implications for Weed, Insect and

DiseaseManagement. Canadian Weed Society, Quebéc, pp 39–67

Mody K, Lerch D, Müller AK, et al (2020) Flower power in the city: Replacing roadside shrubs by wildflower meadows increases insect numbers and reduces maintenance costs. PLoS One 15:1–29. https://doi.org/10.1371/journal.pone.0234327

Mora A, Wilby A, Menéndez R (2021) Abandonment of cultural landscapes: butterfly communities track the advance of forest over grasslands. J Insect Conserv 26:85–96. https://doi.org/10.1007/s10841-021-00365-0

Mottershead D, Underwood E (2020) Pollinators in the CAP: integrating pollinator conservation into the Common Agricultural Policy. Brussels

Muinde J, Katumo DM (2024) Beyond bees and butterflies: The role of beetles in pollination system. J Nat Conserv 77:126523. https://doi.org/10.1016/j.jnc.2023.126523

Müller U, Bruninga-Socolar B, Brokaw J, et al (2024) Integrating perspectives on ecology , conservation value , and policy of bee pollinator seed mixes. Front Ecol Environ e2715. https://doi.org/10.1002/fee.2715

Muratet A, Fontaine B (2015) Contrasting impacts of pesticides on butterflies and bumblebees in private gardens in France. Biol Conserv 182:148–154. https://doi.org/10.1016/j.biocon.2014.11.045

NBDC (2020) All-Ireland Pollinator Plan 2021-2025. Waterford

Neumüller U, Burger H, Schwenninger HR, et al (2021) Prolonged blooming season of flower plantings increases wild bee abundance and richness in agricultural landscapes. Biodivers Conserv 30:3003–3021. https://doi.org/10.1007/s10531-021-02233-4

Noordijk J, Delille K, Schaffers AP, Sýkora K V. (2009) Optimizing grassland management for flower-visiting insects in roadside verges. Biol Conserv 142:2097–2103. https://doi.org/10.1016/j.biocon.2009.04.009

Norton BA, Bending GD, Clark R, et al (2019) Urban meadows as an alternative to short mown grassland: effects of composition and height on biodiversity. Ecol Appl 29:1095–1115. https://doi.org/10.1002/eap.1946

O'Sullivan OS, Holt AR, Warren PH, Evans KL (2017) Optimising UK urban road verge contributions to biodiversity and ecosystem services with cost-effective management. J Environ Manage 191:162–171. https://doi.org/10.1016/j.jenvman.2016.12.062

ODWMS (2023) Operational drought and water scarcity management system. https://aszalymonitoring.vizugy.hu/index.php?lang=eng. Accessed 16 Jan 2023

Ollerton J (2017) Pollinator Diversity: Distribution, Ecological Function, and Conservation. Annu Rev Ecol Evol Syst 48:353–376. https://doi.org/10.1146/annurev-ecolsys-110316-022919

Orford KA, Vaughan IP, Memmott J (2015) The forgotten flies: The importance of non-syrphid Diptera as pollinators. Proc R Soc B Biol Sci 282:. https://doi.org/10.1098/rspb.2014.2934

Pauleit S, Ambrose-Oji B, Andersson E, et al (2019) Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project. Urban For Urban Green 40:4–16. https://doi.org/10.1016/j.ufug.2018.10.006

Pellaton R, Csecserits A, Szitár K, et al (2023) Grazing and boundaries favour weedy plants with functional traits beneficial for pollinators. Glob Ecol Conserv 48:e02717. https://doi.org/10.1016/j.gecco.2023.e02717

Persson AS, Ekroos J, Olsson P, Smith HG (2020) Wild bees and hoverflies respond differently to urbanisation, human population density and urban form. Landsc Urban Plan 204:103901. https://doi.org/10.1016/j.landurbplan.2020.103901

Phillips BB, Wallace C, Roberts BR, et al (2020) Enhancing road verges to aid pollinator conservation: A review. Biol Conserv 250:108687. https://doi.org/10.1016/j.biocon.2020.108687

Piano E, Souffreau C, Merckx T, et al (2019) Urbanization drives cross-taxon declines in abundance and diversity at multiple. Glob Chang Biol 26:1196– 1211. https://doi.org/https://doi.org/10.1111/gcb.14934

Potts SG, Biesmeijer JC, Kremen C, et al (2010) Global pollinator declines: Trends, impacts and drivers. Trends Ecol Evol 25:345–353. https://doi.org/10.1016/j.tree.2010.01.007

Potts SG, Vulliamy B, Roberts S, et al (2005) Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. Ecol Entomol 30:78–85. https://doi.org/10.1111/j.0307-6946.2005.00662.x

Prendergast KS, Dixon KW, Bateman PW (2022) A global review of determinants of native bee assemblages in urbanised landscapes. Insect Conserv Divers 385–405. https://doi.org/10.1111/icad.12569

Rada P, Bogusch P, Pech P, et al (2023) Active management of urban fruit orchard meadows is important for insect diversity. Ecol Eng 186:. https://doi.org/10.1016/j.ecoleng.2022.106833

Rahimi E, Barghjelveh S, Dong P (2021) How effective are artificial nests in attracting bees? A review. J Ecol Environ 45:. https://doi.org/10.1186/s41610-021-00192-z

Rasmussen C, Dupont YL, Mosbacher JB, et al (2013) Strong impact of temporal resolution on the structure of an ecological network. PLoS One 8:. https://doi.org/10.1371/journal.pone.0081694

Renzl B (2008) Trust in management and knowledge sharing: The mediating effects of fear and knowledge documentation. Omega 36:206–220. https://doi.org/10.1016/j.omega.2006.06.005

Resasco J, Chacoff NP, Vázquez DP (2021) Plant–pollinator interactions between generalists persist over time and space. Ecology 102:1–7. https://doi.org/10.1002/ecy.3359

Roulston TH, Goodell K (2011) The role of resources and risks in regulating wild bee populations. Annu Rev Entomol 56:293–312. https://doi.org/10.1146/annurev-ento-120709-144802

Salisbury A, Armitage J, Bostock H, et al (2015) Enhancing gardens as habitats for flower-visiting aerial insects (pollinators): should we plant native or exotic species? J Appl Ecol 52:Salisbury A, Armitage J, Bostock H, Perry J, Tatch. https://doi.org/10.1111/1365-2664.12499

Samu F, Elek Z, Růžičková J, et al (2023) Can Gap-Cutting Help to Preserve Forest Spider Communities? Diversity 15:. https://doi.org/10.3390/d15020240

Sárospataki M, Báldi A, Batáry P, et al (2009) Factors affecting the structure of bee assemblages in extensively and intensively grazed grasslands in Hungary. Community Ecol 10:182–188. https://doi.org/10.1556/ComEc.10.2009.2.7

Scherber C, Beduschi T, Tscharntke T (2019) Novel approaches to sampling pollinators in whole landscapes: a lesson for landscape-wide biodiversity monitoring. Landsc Ecol 34:1057–1067. https://doi.org/10.1007/s10980-018-0757-2

Shwartz A, Turbé A, Simon L, Julliard R (2014) Enhancing urban biodiversity and its influence on city-dwellers: An experiment. Biol Conserv 171:82–90. https://doi.org/10.1016/j.biocon.2014.01.009

Sipos J (2020) Méhlegelő ültetés oktatófilm.

https://siposgazda.hu/blog/szaktanacsadas/mehlegelo-ultetes-oktatofilm. Accessed 12 Apr 2023

Skórka P, Lenda M, Moroń D, et al (2013) Factors affecting road mortality and the suitability of road verges for butterflies. Biol Conserv 159:148–157. https://doi.org/10.1016/j.biocon.2012.12.028

Soga M, Gaston KJ (2022) Towards a unified understanding of human–nature interactions. Nat Sustain 5:374–383. https://doi.org/10.1038/s41893-021-00818-z

Southon GE, Jorgensen A, Dunnett N, et al (2017) Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. Landsc Urban Plan 158:105–118. https://doi.org/10.1016/j.landurbplan.2016.08.003

Stieglitz S, Wilms K, Mirbabaie M, et al (2020) When are researchers willing to share their data? – Impacts of values and uncertainty on open data in academia. PLoS One 15:1–20. https://doi.org/10.1371/journal.pone.0234172

Süle G, Kovács-Hostyánszki A, Sárospataki M, et al (2023a) First steps of pollinator-promoting interventions in Eastern European urban areas – positive outcomes, challenges, and recommendations. Urban Ecosyst 26:1783–1797. https://doi.org/10.1007/s11252-023-01420-1

Süle G, Miholcsa Z, Molnár C, et al (2023b) Escape from the garden: spreading, effects and traits of a new risky invasive ornamental plant (Gaillardia aristata Pursh). NeoBiota 83:43–69. https://doi.org/10.3897/neobiota.83.97325

Szigeti V, Korösi Á, Harnos A, et al (2016) Measuring floral resource availability for insect pollinators in temperate grasslands - A review. Ecol Entomol 41:231–240. https://doi.org/10.1111/een.12298

Szigeti V, Kőrösi Á, Harnos A, Kis J (2018) Temporal changes in floral resource availability and flower visitation in a butterfly. Arthropod Plant Interact 12:177–189. https://doi.org/10.1007/s11829-017-9585-6

Takács N (2021) Extenzíven kezelt gyepek Budapesten. In: Beporzók védelme és települési zöldfelületek. Budapest, pp 1–12

Theodorou P, Albig K, Radzevičiūtė R, et al (2017) The structure of flower visitor networks in relation to pollination across an agricultural to urban gradient. Funct Ecol 31:838–847. https://doi.org/10.1111/1365-2435.12803

Thomas RC, Schultz CB (2016) Resource selection in an endangered butterfly: Females select native nectar species. J Wildl Manage 80:171–180. https://doi.org/10.1002/jwmg.987

Thompson A, Frenzel M, Schweiger O, et al (2021) Pollinator sampling methods influence community patterns assessments by capturing species with different traits and at different abundances. Ecol Indic 132:108284. https://doi.org/10.1016/j.ecolind.2021.108284

Timberlake TP, Vaughan IP, Memmott J (2019) Phenology of farmland floral resources reveals seasonal gaps in nectar availability for bumblebees. J Appl Ecol 56:1585–1596. https://doi.org/10.1111/1365-2664.13403

Tinsley MJ, Simmons MT, Windhager S (2006) The establishment success of native versus non-native herbaceous seed mixes on a revegetated roadside in Central Texas. Ecol Eng 26:231–240. https://doi.org/10.1016/j.ecoleng.2005.10.004

Török P, Dembicz I, Dajic-Stevanovic Z, Kuzemko A (2020) Grasslands of eastern Europe. Encycl World's Biomes 3–5:703–713. https://doi.org/10.1016/B978-0-12-409548-9.12042-1

Tremblay L, Underwood E (2023) Guidelines for monitoring pollinators in urban habitats

Turo KJ, Gardiner MM (2019) From potential to practical: conserving bees in urban public green spaces. Front Ecol Environ 17:167–175. https://doi.org/10.1002/fee.2015

UFZ (2024) SPRING: Strengthening Pollinator Recovery through INdicators and monitorinG

UKCEH (2021) UK Pollinator Monitoring Scheme: Flower-Insect Timed Count guidance. Wallingford

Underwood E, Darwin G, Gerritsen E (2017) Pollinator Initiatives in EU Member States: Success Factors and Gaps. 67

Unterweger PA, Klammer J, Unger M, Betz O (2018) Insect hibernation on urban green land: A winter-adapted mowing regime as a management tool for insect conservation. BioRisk 2018:1–29. https://doi.org/10.3897/biorisk.13.22316

Valkó O, Török P, Deák B, Tóthmérész B (2014) Review: Prospects and limitations of prescribed burning as a management tool in European grasslands. Basic Appl Ecol 15:26–33. https://doi.org/10.1016/j.baae.2013.11.002

Valtonen A, Saarinen K, Jantunen J (2006) Effect of different mowing regimes on butterflies and diurnal moths on road verges. Anim Biodivers Conserv 29:133–148

van Klink R, Bowler DE, Gongalsky KB, et al (2023) Disproportionate declines of formerly abundant species underlie insect loss. Nature. https://doi.org/10.1038/s41586-023-06861-4

Vanbergen AJ, Aizen MA, Cordeau S, et al (2020) Transformation of agricultural landscapes in the Anthropocene: Nature’s contributions to people, agriculture and food security, 1st edn. Elsevier Ltd.

Venables WN, Ripley BD (2002) Modern Applied Statistics with S, 4th edn. New York

Vmeteo (2022) 2021. éves összesítő. https://vmeteo.hu/2021-eves-osszesito. Accessed 1 Apr 2023

Vujić A, Gilbert F, Flinn G, et al (2022) Pollinators on the edge: our European hoverflies. The European Red List of Hoverflies. European Commission, Brussels, Belgium

Walcher R, Hussain RI, Sachslehner L, et al (2019) Long-term abandonment of mountain meadows affects bumblebees, true bugs and grasshoppers: A case study in the Austrian ALPS. Appl Ecol Environ Res 17:5887–5908. https://doi.org/10.15666/aeer/1703_58875908

Wastian L, Unterweger PA, Betz O (2016) Influence of the reduction of urban lawn mowing on wild bee diversity (Hymenoptera, Apoidea). J Hymenopt Res 49:51–63. https://doi.org/10.3897/JHR.49.7929

Wenzel A, Grass I, Belavadi V V., Tscharntke T (2020) How urbanization is driving pollinator diversity and pollination – A systematic review. Biol Conserv 241:108321. https://doi.org/10.1016/j.biocon.2019.108321

Westbury DB, Woodcock BA, Harris SJ, et al (2017) Buffer strip management to deliver plant and invertebrate resources for farmland birds in agricultural landscapes. Agric Ecosyst Environ 240:215–223. https://doi.org/10.1016/j.agee.2017.02.031

Wikipedia (2023a) Veszprém. https://hu.wikipedia.org/wiki/Veszprém. Accessed 1 Apr 2023

Wikipedia (2023b) Budapest. https://hu.wikipedia.org/wiki/Budapest. Accessed 1 Apr 2023

Wilk B, Rebollo V, Hanania S (2019) A guide for pollinator-friendly cities: How can spatial planners and landuse managers create favourable urban environments for pollinators?

Winqvist C, Ahnström J, Bengtsson J (2012) Effects of organic farming on biodiversity and ecosystem services: Taking landscape complexity into account. Ann N Y Acad Sci 1249:191–203. https://doi.org/10.1111/j.1749-6632.2011.06413.x

Wintergerst J, Kästner T, Bartel M, et al (2021) Partial mowing of urban lawns supports higher abundances and diversities of insects. J Insect Conserv 25:797–808. https://doi.org/10.1007/s10841-021-00331-w

Woodard SH, Federman S, James RR, et al (2020) Towards a U.S. national program for monitoring native bees. Biol Conserv 252:. https://doi.org/10.1016/j.biocon.2020.108821

Zografou K, Sfenthourakis S, Pullin A, Kati V (2009) On the surrogate value of red-listed butterflies for butterflies and grasshoppers: A case study in Grammos site of Natura 2000, Greece. J Insect Conserv 13:505–514. https://doi.org/10.1007/s10841-008-9198-6

Zuur AF, Ieno EN, Walker NJ, et al (2009) Mixed Effects Models and Extensions in Ecology with R. Springer, New York