Reduced mowing frequencies increase pollinator abundance in urban lawns in the UK

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SUMMARY

Insect pollinators are currently declining, in part due to the loss of habitats and foraging resources. However, one potential source of refuge is lawns in urban areas and the floral resources within them. Lawns represent a substantial proportion of urban green space and, if managed with pollinators in mind, could become a major component of a matrix of foraging resources. This study used Ministry of Justice prison and court sites as a case study for the management of urban lawn space. Sites contained four patches, one control patch mown as normal every two weeks and then three patches mown either every four, six or 12 weeks. Weekly pollinator and flowering plant surveys were completed at each site over 12 weeks from June – August 2023. We found that patches with less frequent mowing (every six and 12 weeks) had a significantly higher abundance of pollinators, >170% higher than the typically used mowing frequency of every two weeks. Lawns left unmown for 12 weeks also had higher floral species richness and flower cover than lawns mown every two weeks. Consequently, we recommend that lawns within urban and suburban building complexes are mown at an interval of at least six, but ideally 12, weeks to improve floral resources and pollinator abundance.

BACKGROUND

Pollinating insects are a diverse group of ecosystem service providers to crops and wildflowers, with 80% of plants relying on pollinators to some extent (Potts *et al.* 2016). Many pollinator populations are in decline, which is a source of global concern (Potts *et al.* 2016). These declines are driven largely by habitat loss and fragmentation, resulting in a loss of foraging resources for pollinators (Potts *et al.* 2016). However, there is growing evidence that urban areas can serve as critical hotspots for pollinator biodiversity and conservation (Baldock *et al.* 2015, 2019; Hall *et al.* 2017; Theodorou *et al.* 2020).

Grass lawns are a dominant habitat in urban areas, where they are found in private gardens, urban parks, and surrounding buildings and roads. Grass lawns represent 75% of urban green space in the UK (Ignatieva *et al.* 2015). Grass lawns are typically amenity grassland, usually used for recreation, that are characterised by short sward and contain very few species. Depending on their management, grass lawns can host plant species that provide floral resources for pollinators, including species such as dandelion (*Taraxacum officinale*) and white clover (*Trifolium repens*) (Larson *et al.* 2014). Given that grass lawns are ubiquitous in urban areas, the management of grass for pollinators could be used as an opportunity to create a mosaic of foraging resources and refugia for pollinators in urban areas. One such opportunity for management is grass lawns within commercial and governmental building complexes. Such spaces are increasing due to economic shifts from production to services (Barnett 2017) with many found in suburban areas. As such, appropriate management of these sites may present an opportunity to enhance pollinator biodiversity.

Conservation Evidence actions testing the effectiveness of changing mowing regimes in urban areas predominantly focus on urban parks and road verges (Bladon *et al.* 2023). Current evidence suggests that reducing mowing intensity to less than twice a year can increase floral resources on grass verges (Jakobsson *et al.* 2018) and urban parks (Rudolph *et al.* 2017). Further, this increase in floral resources resulted in improved pollinator communities (Hemmings *et al.* 2022; Jakobsson *et al.* 2018; Noordijk *et al.* 2009; Saarinen *et al.* 2005) including butterflies and wild bees, and increased the diversity of rare taxa (Proske *et al.* 2022). However, some studies have shown similar benefits to pollinators with more frequent mowing (more than twice a year) (Halbritter *et al.* 2015). Given that conservation in urban areas has to balance human needs and perspectives with ecological benefits, aesthetics and security also need to be considered when designing optimal mowing regimes.

In this study, we test the effectiveness of different mowing frequency on availability of floral resources to

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pollinators and whether this could increase pollinator communities in urban and suburban building complexes. Our study system was the UK prison and court network in collaboration with the UK Ministry of Justice (MoJ), which manages nearly 3,000 ha of land across the UK. Our specific aim is to understand if floral resources and, in turn, pollinator abundance and taxonomic richness can be increased by reducing mowing frequency from the typical frequency of every two weeks on MoJ sites.

All sites used in this study were MoJ prisons or court sites (Figure 1). Sites voluntarily opted into completing the study following an initial recruitment email. Each of these sites was a mixture of buildings, impervious surfaces and grass habitats. Some sites also contained orchards, woodlands, vegetable patches, herb gardens, and ponds. Initially, 45 sites showed interest in completing the study. However, data was not received from 40 sites due to lack of staffing, security issues, contractors mowing experimental patches, and the completion of only a subset of the study.

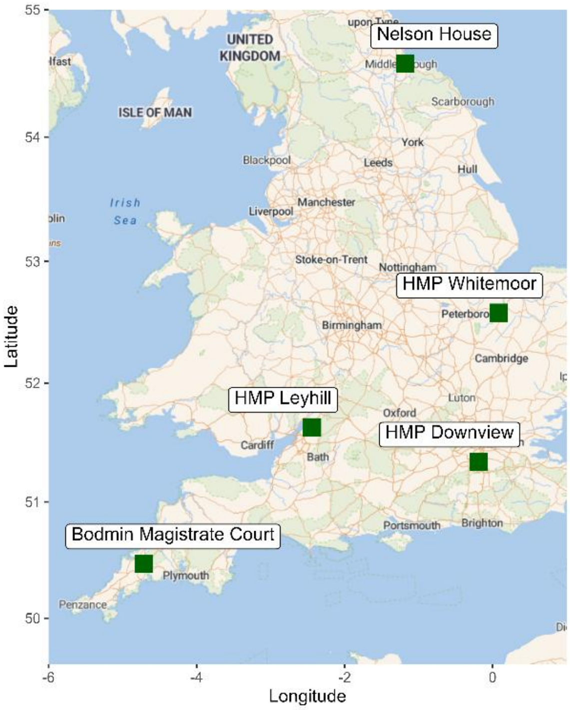

Figure 1: Map of the five prisons, courts or rehabilitation sites used in the study in the UK. Bodmin Magistrate Court, HMP Downview, HMP Leyhill and HMP Whitemore completed the floral and pollinator surveys, whilst Bodmin Magistrate Court, HMP Downview, HMP Leyhill and Nelson House completed the site survey. Map is a Stadia Map (OpenStreetMap generated by stadiamaps.com, openstreetmap.org/copyright).

ACTION

At each site, four separate patches (>10 m^2) were mowed, following one of four mowing regimes. All patches were initially mowed in the week commencing 5 June 2023, then subsequently following a given mowing frequency. One patch was mowed every two weeks to act as a control, given that two weeks was the most common mowing frequency employed at sites prior to our study. The three additional treatments at each site were, (i) mowing every four weeks, (ii) mowing every six weeks, and (iii) leaving patches unmown for 12 weeks. Due to the variation in mowing equipment across sites, it was not feasible to control mowing length and removal of grass clippings. However, where possible, landscaping contractors were advised to set their mower to a cutting length of 30-40 mm.

Monitoring

Monitoring was carried out by prison staff members and offenders, all of whom received an information pack with an introduction to and instructions for the study, and an identification guide for both pollinators and common plants. Pollinator and plant surveys were undertaken weekly on each patch for a total of twelve weeks between 14 June 2023 and 28 August 2023.

Pollinator surveys

Flower-visiting insect (pollinator) community data was recorded. To do this, 2 m^2 observation squares were placed in the middle of experimental patches and participants watched activity in the 2 m^2 square within each treatment for 10 minutes. A pilot study on the ability of untrained members of the public to differentiate honeybees, bumblebees, solitary bees and hoverflies was completed prior to the study. From this study, solitary bees and hoverflies were less successfully differentiated from bumblebees and honeybees. Subsequently, the level of identification was chosen to maximise the reliability of accurate identification by members of the public who did not have previous knowledge of pollinators. Therefore, insects visiting flowers were identified to the level of beetles, butterflies/moths, bumblebees, and honeybees, and counted; these are referred to as pollinators throughout this paper. The total abundance of pollinators recorded in each survey and the number of aforementioned groups observed, hereafter known as taxonomic richness, were recorded.

Although instructions stated that surveys were not to be completed on rainy and windy days and only

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within daylight hours, weather during surveys was recorded to verify that these instructions were followed.

Plant surveys

Plant surveys were completed after the pollinator surveys in a 1 m^2 subset of the 2 m^2 patches. Within this area, the maximum vegetation height was recorded, along with three measures of floral resources: (i) floral cover was visually estimated as a percentage of the 1 m^2 area covered by open flowers (%) and (ii) the presence of 12 common lawn species was recorded (floral richness) (Table 1).

Site Surveys

A staff member from each site was asked to complete a site questionnaire to report information about site details, habitats present on the site, and the presence of managed honeybee hives. Respondents were also asked about the benefits and costs of the study in terms of financial cost, time, security, aesthetics, and perceived added biodiversity to the site, as well as the perceptions of site users in response to the reduced mowing regimes.

Table 1: The 12 common lawn flower species presented in the identification guide and whose presence was recorded. Number of occurrences in individual patches in each of 12 weekly surveys is recorded for the overall study and by each mowing frequency.

Species in flower identification list	Overall number of patches where species was present	Number of treatment patches in which species was present			
		Mown every 2 weeks	Mown every 4 weeks	Mown every 6 weeks	Unmown (12 weeks)
Selfheal *(Prunella vulgaris)*	83	18	21	20	24
Dandelion *(Taraxacum officinale)*	65	14	12	16	23
Daisy *(Bellis perennis)*	56	13	15	12	16
Creeping buttercup *(Ranunculus repens)*	55	10	15	14	16
White clover *(Trifolium repens)*	44	10	8	10	16
Bird's foot trefoil *(Lotus corniculatus)*	37	10	7	10	10
Common mouse-ear *(Cerastium fontanum)*	37	4	12	8	13
Dove's foot cranesbill *(Geranium molle)*	17	3	4	6	4
Cuckooflower *(Cardamine pratensis)*	9	1	2	3	3
Speedwell *(Veronica spp.)*	7	1	2	2	2
Forget-me-not *(Myosotis sylvatica)*	5	0	1	1	3
Mouse-ear hawkweed *(Pilosella officinarum)*	3	1	0	2	0

Data analysis

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The analysis was conducted in R version 4.1.2 and RStudio version 2021.09.1 (R Core Team 2021; RStudio Team 2020). Generalised linear mixed models (GLMMs) (for floral richness) were built using the lme4 package (Bates *et al.* 2015). The GLMMs (for percentage cover) and zero-inflated models (for pollinator abundance and taxonomic richness) were built using the glmmTMB package (Brooks *et al.* 2017). In all cases, the model residuals, homogeneity of variance and overdispersion were verified using the Dharma package (Hartig & Lohse 2022). Collinearity was checked using the variance inflation factor (vif) with a cut-off of 2.5 and no variable exceeded this cut-off (Johnston *et al.* 2018). Subsequent post-hoc comparisons between mowing regimes were completed using a Tukey test using the multcomp package (Westfall *et al.* 2011).

For floral surveys, a GLMM with a Poisson distribution was used to analyse floral richness. A GLMM with a beta distribution was used to analyse the percentage cover of flowers (as a proportion) (Salinas Ruíz *et al.* 2023). Floral cover data was transformed to avoid zeros and ones in the data using the transformation $y' = (y * (n-1) + 0.5) / n$ (Smithson & Verkuilen 2006). For both floral response variables, models included the mowing regime as a categorical fixed factor, with control (mowing every two weeks) as the reference, and the survey week and site name as random effects.

For pollinator surveys, a zero-inflated GLMM with a Poisson distribution was used to analyse both total abundance and taxonomic richness. For both pollinator response variables, the mowing regime, a participant-reported presence of rain during the survey (yes or no), floral species richness, and the interaction between floral species richness and mowing frequency were included as fixed factors. Survey week and site name were included as random effects. Floral cover could not be included due to the low number of responses from one site. AICc was used to select the most likely models nested within the maximal models. The model exhibiting the lowest AICc value was chosen as the model with the greatest explanatory power. When two models were indistinguishable in terms of explanatory power ($\Delta AICc \leq 2$), model averaging was used and presented in the text (Barton 2012).

CONSEQUENCES

A total of 362 pollinators were counted across all sites. Of these, 42% were butterflies, 30% were bumblebees, 5% were honeybees, and 23% were beetles. All 13 plant species were recorded during the study, but selfheal (*Prunella vulgaris*), daisy (*Bellis perennis*), dandelion (*Taraxacum officinale*), creeping buttercup (*Ranunculus repens*), and white clover (*Trifolium repens*) were most common (top 5 ranked plants in terms of occurrence)

Floral species richness was significantly higher in patches of lawns left unmown for 12 weeks compared to control patches mown every two weeks (β = 0.37, 95% CI [0.10, 0.64]) but did not significantly differ from patches mown every four and six weeks (Figure 2). Control patches mown every two weeks did not differ from patches mown every four and six weeks.

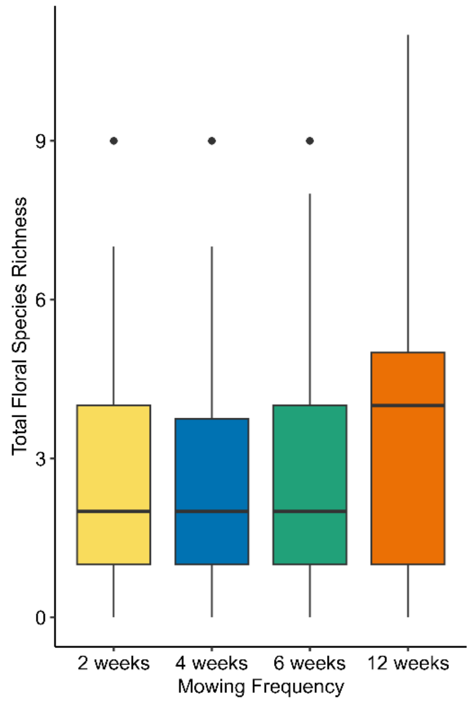

Figure 2: Total floral species richness observed in each mowing frequency on each of 12 weekly surveys across four locations, from June-August 2023. The box represents the first (lower line) and third quartiles (upper line). The central line within the box represents the median. The upper and lower whisker extends to the highest and lowest value, respectively, within 1.5 times the interquartile range from the box. Data beyond the end of the whiskers are outliers and plotted as points.

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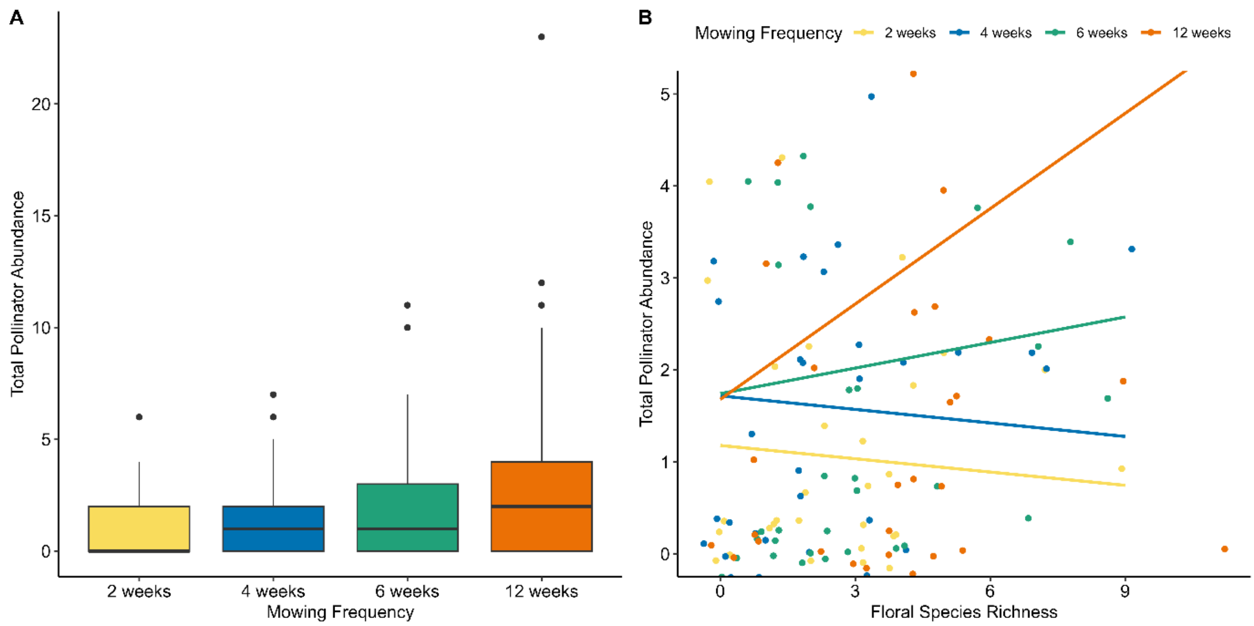

Figure 3: (A) Total pollinator abundance observed visiting flowers in each mowing frequency in each of 12 weekly surveys across four locations from June-August 2023. The box represents the first (lower line) and third quartiles (upper line). The central line within the box represents the median. The upper and lower whisker extends to the highest and lowest value, respectively, within 1.5 times the interquartile range from the box. Data beyond the end of the whiskers are outliers and plotted as points. (B) Plot of total pollinator abundance observed against floral species richness in each of the 12 weekly surveys carried out across four locations during June-August 2023. Points are jittered when data is overlapping. The effect of mowing regime and floral species richness were found to interact, therefore, points are coloured by mowing regime. Further, predicted lines of best fit from the generalised linear model, presented in the text, are plotted and coloured by mowing regime. These lines show that the positive effects of floral species richness are present in the six and 12 week mowing regimes.

The percentage cover of open flowers was significantly higher in patches of lawn mown every 12 weeks compared to control patches mown every two weeks (β = 0.72, 95% CI [0.14, 1.30]). However, no other patches differed in the percentage cover of open flowers.

The abundance of pollinators visiting flowers on lawns was significantly higher in patches mown every six weeks (β = 0.49, 95% CI [0.03, 0.95]) and 12 weeks (β = 0.71, 95% CI [0.26, 1.15]) compared to control patches mown every two weeks (Figure 3). Specifically, patches mown every six and 12 weeks saw, on average, 171% and 179% more pollinators, respectively, than control patches mown every two weeks. There was no significant difference between patches mown every six and 12 weeks. Patches mown every four weeks did not significantly differ from the control patches, or the patches mown every six or 12 weeks.

The abundance of pollinators visiting flowers on lawns was higher in patches with greater floral species richness (β = 0.17, 95% CI [0.07, 0.28]). When the interaction of floral species richness and mowing frequency was considered there was an additional positive influence of floral species richness in lawns mown every 6-weeks (β = 0.14, 95% CI [0.01, 0.28]) and 12 weeks (β = 0.18, 95% CI [0.05, 0.32]).

The taxonomic richness of pollinators did not significantly differ across patches. However, floral species richness was positively associated with the taxonomic richness of pollinators visiting flowers on lawns (β = 0.15, 95% CI [0.06, 0.23]).

Costs and benefits

The reduction in mowing resulting from the study was linked to lower fuel use by land management teams at three of the four sites that replied to the site survey. One site quantified this saving as £40 less spent on fuel across the 12 weeks (£0.24/m^2) All four sites responded that the less frequent mowing had a positive effect on the wellbeing of staff and/or prisoners. Three sites reported aesthetic benefits of less frequent mowing, with responses describing patches as “inviting” and “visually pleasing”, as well as describing the general aesthetic benefits of more wildflowers. Further benefits to wellbeing were reported from three sites, and while these were not

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quantified, they were described as more opportunities to engage with nature (two sites) and uplift in wellbeing from the participating prisoner population (one site). However, one site described the less frequently mown patches as “untidy”. Further, this site also flagged, from a security perspective, the “potential [for] hiding in longer grass”.

DISCUSSION

We showed that reducing mowing frequency from the typical two-week regime being used at sites prior to our study, to mowing either every six or 12 weeks, can increase the number of pollinators visiting flowers on lawns by over 170%. Floral species richness was also doubled on patches mown every 12 weeks compared to patches mown every two weeks, and, in turn, pollinator abundance and taxonomic richness were higher on patches with higher floral species richness. We therefore recommend that grassed areas within commercial and governmental building complexes are left unmown for at least six weeks. Further, we recommend that plots are left for 12 weeks during key periods for pollinators, or mown asynchronously.

Leaving patches unmown for 12 weeks increased floral species richness and flower percentage cover compared to a typical two-week mowing regime, and this in turn increased pollinator abundance. Interestingly, while floral resources were not significantly more abundant in patches mown every six weeks, the number of pollinators was significantly higher than the control patches and did not differ from lawns mown every 12 weeks. This suggests that higher pollinator abundance was driven both by increased floral resources and by some direct effect of reduced mowing frequency. For example, this may be due to a decrease in direct pollinator mortality from mowing, an effect previously observed in honeybees (Fluri & Frick 2002) and in butterflies and moths (Humbert *et al.* 2009). Despite the focus of many previous studies being on mowing frequencies less than twice per year, (e.g. (Halbritter *et al.* 2015; Jakobsson *et al.* 2018; Noordijk *et al.* 2009; Proske *et al.* 2022; Süle *et al.* 2023)), our results show that reducing mowing frequency to between 6-12 weeks can benefit foraging resources and pollinator abundances, in line with results seen for butterfly abundance on road verges (Halbritter *et al.* 2015).

Sites participating in this study also had reduced fuel costs associated with this management. Given that sites were still completing mows for all four frequencies during the study period, this cost saving is likely to increase if reduced mowing frequency was rolled out across all lawns on the sites. Further, participants largely reported no hindrance of the new mowing regimes to security, a key issue in this organisation and others like it. However, concerns were raised over the potential of prisoners hiding when the grass got longer. Participation in the study was reported to benefit prisoner wellbeing, but increasing visibility of nature by reducing mowing could also enhance wellbeing (Russell *et al.* 2013). Previous studies indicate that prisoners with views of farmland require less healthcare than those overlooking courtyards (Moore 1980; Russell *et al.* 2013). Therefore, use of reduced mowing throughout sites may lead to similar favourable effects on prisoner health and wellbeing.

With habitat loss reducing the floral resources available to pollinators, our results show that prolonged periods of not mowing, for at least six weeks in urban lawns in building complexes, can provide foraging refugia for urban pollinators. Furthermore, when considering both plants and pollinators, not mowing for 12 weeks may be more beneficial. Mowing every 12 weeks may also increase the long-term viability of this conservation intervention by allowing sufficient time for wildflowers to produce seeds. In contrast to previous studies, we focus on intervals between mowing of six-12 weeks, as opposed to reducing mowing to twice yearly or annually. Abandoning mowing on lawns is often met with resistance for security and aesthetic reasons (Ignatieva *et al.* 2015), but our results suggest that extended yet still more frequent mowing regimes can deliver ecological benefits without compromising these key issues. Consequently, our results provide a novel option for management of urban lawns to deliver benefits to pollinators. Our recommendations may also provide more palatable conservation advice for members of the public, especially in the context of urban areas, which are human-dominated landscapes. It is possible that the benefits seen in this study could increase if followed for several years (Fisher & Rahmann 1997) or combined with rotational mowing to avoid simultaneous removal of all floral resources from a site (Bubová *et al.* 2015).

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REFERENCES

Baldock K.C.R., Goddard M.A., Hicks D., Kunin W., Mitschunas N., Morse H., Osgathorpe L.M., Potts S., Robertson K.M., Scott A.V., Staniczenko P.P.A., Stone G., Vaughan I. & Memmott J. (2019) A systems approach reveals urban pollinator hotspots and conservation opportunities. *Nature. Ecology & Evolution*, **3**, 363–373. 10.1038/s41559-018-0769-y.

Baldock K.C.R., Goddard M.A., Hicks D.M., Kunin W.E., Mitschunas N., Osgathorpe L.M., Potts S.G., Robertson K.M., Scott A.V., Stone G.N., Vaughan I.P. & Memmott J. (2015) Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B: Biological Sciences*, **282**, 20142849. 10.1098/rspb.2014.2849

Barnett J. (2017) *Redesigning cities: Principles, practice, implementation*. Routledge, New York.

Barton K. (2012) MuMIn: Multi-model inference. R package version 1.7. **2**. *http://CRAN. R-project. org/package= MuMIn*.

Bates D., Mächler M., Bolker B. & Walker S. (2015) Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software.*, **67**. 10.18637/jss.v067.i01.

Bates D., Mächler M., Bolker B. & Walker S. (2015) Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software.*, **67**. 10.18637/jss.v067.i01.

Bubová T., Vrabec V., Kulma M. & Nowicki P. (2015) Land management impacts on European butterflies of conservation concern: a review. *Journal of Insect Conservation*, **19**, 805–821. 10.1007/s10841-015-9819-9.

Fisher, G. & Rahmann, G. (1997) Extensification - benefits and disadvantages to grassland biodiversity. In: (ed. M. Kołpakeditor) Presented at the Management for grassland biodiversity. Proceedings of the International Occasional Symposium of the European Grassland Federation, Warszawa-Łomża, Poland, 19-23 May, 1997., Organizing Committee of the International Occasional Symposium of the European Grassland Federation, pp. 115–123.

Fluri P. & Frick R. (2002) Honey bee losses during mowing of flowering fields. *Bee World*, **83**, 109–118. 10.1080/0005772X.2002.11099550.

Halbritter D.A., Daniels J.C., Whitaker D.C. & Huang L. (2015) Reducing mowing frequency increases floral resource and butterfly (Lepidoptera: Hesperioidea and Papilionoidea) abundance in managed roadside margins. *Florida Entomologist*, **98**, 1081–1092.

Hall D.M., Camilo G.R., Tonietto R.K., Ollerton J., Ahrné K., Arduser M., Ascher J.S., Baldock K.C.R., Fowler R., Frankie G., Goulson D., Gunnarsson B., Hanley M.E., Jackson J.I., Langellotto G., Lowenstein D., Minor E.S., Philpott S.M., Potts S.G., Sirohi M.H., Spevak E.M., Stone G.N., Threlfall C.G. (2017) The city as a refuge for insect pollinators. *Conservation Biology*, **31**, 24–29. 10.1111/cobi.12840.

Hartig F. & Lohse L. (2022) DHARMa: Residual diagnostics for hierarchical (multi-level / mixed) regression models. 10.32614/CRAN.package.DHARMa

Hemmings K., Elton R. & Grange I. (2022) No-mow amenity grassland case study: Phenology of floral abundance and nectar resource. *Ecological Solutions and Evidence*, **3**, e12179. 10.1002/2688-8319.12179.

Humbert J.-Y., Ghazoul J. & Walter T. (2009) Meadow harvesting techniques and their impacts on field fauna. *Agriculture, Ecosystems & Environment*, **130**, 1–8. https://doi.org/10.1016/j.agee.2008.11.014.

Humbert J.-Y., Pellet J., Buri P. & Arlettaz R. (2012) Does delaying the first mowing date benefit biodiversity in meadowland? *Environmental Evidence*, **1**, 9. 10.1186/2047-2382-1-9.

Ignatieva M., Ahrné K., Wissman J., Eriksson T., Tidåker P., Hedblom M., Kätterer T., Marstorp H., Berg P., Eriksson T. & Bengtsson J. (2015) Lawn as a cultural and ecological phenomenon: A conceptual framework for transdisciplinary research. *Urban Forestry & Urban Greening*, **14,** 383-387. 2.10.1016/j.ufug.2015.04.003.

ISSN 1758-2067

Humbert J.-Y., Pellet J., Buri P. & Arlettaz R. (2012) Does delaying the first mowing date benefit biodiversity in meadowland? *Environmental Evidence*, **1**, 9. 10.1186/2047-2382-1-9

Johnston, R., Jones, K. & Manley, D. (2018) Confounding and collinearity in regression analysis: a cautionary tale and an alternative procedure, illustrated by studies of British voting behaviour. *Quality & Quantity*, **52**, 1957–1976. 10.1007/s11135-017-0584-6.

Larson J.L., Kesheimer A.J. & Potter D.A. (2014) Pollinator assemblages on dandelions and white clover in urban and suburban lawns. *Journal of Insect Conservation*, **18**, 863–873. 10.1007/s10841-014-9694-9.

Moore E.O. (1980) A prison environment: Its effect on healthcare utilization. Thesis. University of Michigan.

Noordijk J., Delille K., Schaffers A.P. & Sýkora K.V. (2009) Optimizing grassland management for flower-visiting insects in roadside verges. *Biological Conservation*, **142**, 2097–2103. 10.1016/j.biocon.2009.04.009.

Potts S.G., Imperatriz-Fonseca V., Ngo H., Biesmeijer J.C., Breeze T., Dicks L., Garibaldi L., Settele J., Vanbergen A.J. & Aizen M.A. (2016) *Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on pollinators, pollination and food production*.

Proske A., Lokatis S. & Rolff J. (2022) Impact of mowing frequency on arthropod abundance and diversity in urban habitats: A meta-analysis. *Urban Forestry & Urban Greening*, **76**, 127714. 10.1016/j.ufug.2022.127714.

R Core Team. (2021) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

RStudio Team. (2020) *RStudio: Integrated Development for R.* RStudio, PBC.

Rudolph M., Velbert F., Schwenzfeier S., Kleinebecker T. & Klaus V.H. (2017) Patterns and potentials of plant species richness in high- and low-maintenance urban grasslands. *Applied Vegetation Science*, **20**, 18–27. 10.1111/avsc.12267.

Russell R., Guerry A.D., Balvanera P., Gould R.K., Basurto X., Chan K.M.A., Klain S., Levine J. & Tam J. (2013) Humans and nature: How knowing and experiencing nature affect well-being. *Annual Review of Environment and Resources*, **38**, 473–502. 10.1146/annurev-environ-012312-110838.

Saarinen K., Valtonen A., Jantunen J. & Saarnio S. (2005) Butterflies and diurnal moths along road verges: Does road type affect diversity and abundance? *Biological Conservation*, **123**, 403–412. 10.1016/j.biocon.2004.12.012.

Salinas Ruíz J., Montesinos López O.A., Hernández Ramírez G. & Crossa Hiriart J. (2023) Generalized linear mixed models for proportions and percentages. In: *Generalized Linear Mixed Models with Applications in Agriculture and Biology* (eds. Salinas Ruíz, J., Montesinos López, O.A., Hernández Ramírez, G. & Crossa Hiriart, J.) Springer International Publishing, Cham, pp. 209–278.

Smithson M. & Verkuilen J. (2006) A better lemon squeezer? Maximum-likelihood regression with beta-distributed dependent variables. *Psychological Methods*, **11**, 54–71. 10.1037/1082-989X.11.1.54.

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. 10.1007/s11252-023-01420-1.

Theodorou P., Radzevičiūtė R., Lentendu G., Kahnt B., Husemann M., Bleidorn C., Settele J., Schweiger O., Grosse I., Wubet T., Murray T.E. & Paxton R.J. (2020) Urban areas as hotspots for bees and pollination but not a panacea for all insects. *Nature Communications*, **11**, 576. 10.1038/s41467-020-14496-6.

Westfall P.H., Tobias R.D. & Wolfinger R.D. (2011) *Multiple comparisons and multiple tests using SAS*. SAS Institute.

ISSN 1758-2067