Do bumblebees thrive in Dutch meadow bird reserves (Hymenoptera: Apidae)?

Anthonie Stip
Marco Tanis
Linde Slikboer
Jens Bokelaar

TREFWOORDEN
Bumblebees, flower-rich grasslands, grassland management, meadow bird reserves

Entomologische Berichten 83 (6): 171-177

Flower-rich grasslands are an important habitat for bumblebees. These grassland types are becoming increasingly scarce and therefore many bumblebee species are under pressure. Over 205,000 hectares of mesotrophic grassland are left in the Netherlands, but little is known about their current value for these insects. We therefore studied species richness and abundance of bumblebees in four grassland types on fifteen locations on peat and clay soils in the Netherlands in 2018 and 2019. In total, we found 674 bumblebees of eight different species. Abundance and species richness were significantly lower in meadow bird grasslands than in flower-rich grasslands, hay meadows and road verges. This was mainly caused by a scarcity of flowers in the meadow bird reserves due to high nitrogen fertilization inputs and large scale mowing after the end of the bird breeding season. Suggestions for management improvements that favour bumblebees are made.

Introduction

Flower-rich grasslands are an important habitat for many bumblebee species (Goulson 2010, Westrich 2018). Bumblebees and other pollinators rely on pollen and nectar provided by flowers as a food source for adults and larvae. Reduction in floral resource availability is known to be a major driver of pollinator declines (Goulson *et al*. 2015). For bumblebees, especially the presence of leguminous plants (specifically red clover *Trifolium pratensis*) is very decisive (Dupont *et al*. 2011, Kleijn & Raemakers 2012). Of the 29 bumblebee species known to occur in the Netherlands, seven species are currently extinct, six species are threatened and four species are vulnerable (Reemer 2018). Kleijn & Raemakers (2012) have shown that bumblebees with declining populations (such as *Bombus humilis* and *B. jonellus*) collected pollen on significantly fewer plant taxa than bumblebees with stable populations (such as *B. pascuorum* and *B. lapidarius*). Moreover, a proportion of the plant species on which declining bumblebee species collected their pollen decreased sharply after 1950, in contrast to stable bumblebee species that collected and still collect their pollen on stable or increasing plant species. Land use changes in the last few decades thus are reflected in bumblebee diets. Common bumblebee species were able to move along with these changes, whereas several once widespread bumblebee species were not able to do so and declined strongly. With the decline of blooming clover crops for agricultural use in large parts of northwestern Europe as well as drainage and fertilization of large grassland areas, many of the flower-rich grasslands disappeared (Goulson *et al*. 2005, Potts *et al*. 2009). With them, a lot of bumblebee habitat has been lost and especially clover specialists disappeared from large parts of agricultural landscapes. Many grassland types in the Netherlands are heavily fertilized in recent decades, resulting in productive but species-poor grasslands (Weeda *et al*. 2002). In these grasslands, productive grasses such as ryegrass *Lolium perenne* dominate the vegetation structure and herbaceous plants are systematically outcompeted and sometimes killed with herbicides. For this reason, many of the 956,000 hectares of grasslands in the Netherlands (CBS 2016) are very suitable for agricultural purposes, but likely have limited value as a habitat for pollinators such as bumblebees. Due to their long lasting colonies, bumblebees need floral resources from February until November, although the exact periods differ among species. Many intensively used landscapes in the Netherlands fail to meet these requirements, at least in late spring and summer, resulting in so-called hunger gaps (Timberlake *et al*. 2019).

Over 205,000 hectares of mesotrophic grassland types in the Netherlands are managed for flora and fauna (BIJ12 2020). We selected three of these grassland types, covering 111.000 hectares, which are known in the Dutch subsidy scheme 'Subsidiestelsel voor Natuur en Landschap' as flower-rich grassland ('Flora en faunarijk grasland', type N12.02), hay meadows ('Vochtig hooiland', type N10.02) and meadow bird grassland ('Vochtig weidevogelgrasland', type N13.01). These grasslands are managed by nature conservation organizations like Staatsbosbeheer, Natuurmonumenten and De Landschappen and their tenant farmers. Some of the characteristics of these grasslands are shown in table 1. Until recently, little was known about the value of these grassland types for bumblebees and the effects of the current management in these grasslands on bumblebees. We therefore investigated bumblebee species richness and abundance in moderately nutrient rich grasslands in the project 'Weide Hommelrijk' (Meadows rich in bumblebees) (Stip

Table 1. Characteristics of the four grassland types.
Tabel 1. Kenmerken van de vier graslandtypen.

Grassland type / graslandtype	**SNL type** / SNL-type	**Soil type** / bodemtype	**Management** / beheer	**Number of cuts per year** / aantal maaibeurten per jaar	**Timing of mowing (month)** / tijdstip van maaien (maand)	**Moisture** / vochtigheid	**Fertilization** / bemesting	**Area (ha, 2019)** / oppervlakte (ha, 2019)
Flower-rich grassland	N12.02	Clay, peat, sand	Grazing and/or mowing	1-2	6-7 and/or 9	Moist-dry	Occasionally solid manure	72.012
Hay meadow	N10.02	Clay, peat	Mowing	1	8	Moist-wet	None	16.047
Meadow bird grassland	N13.01	Clay, peat	Grazing and/or mowing; fertilization	2-4	6, 7, 8-9	Moist-dry	Solid manure, slurry	23.436
Road verge	-	Clay, peat, sand	Mowing	1-3	6 and/or 9	Moist-dry	None; nitrogen deposition	-

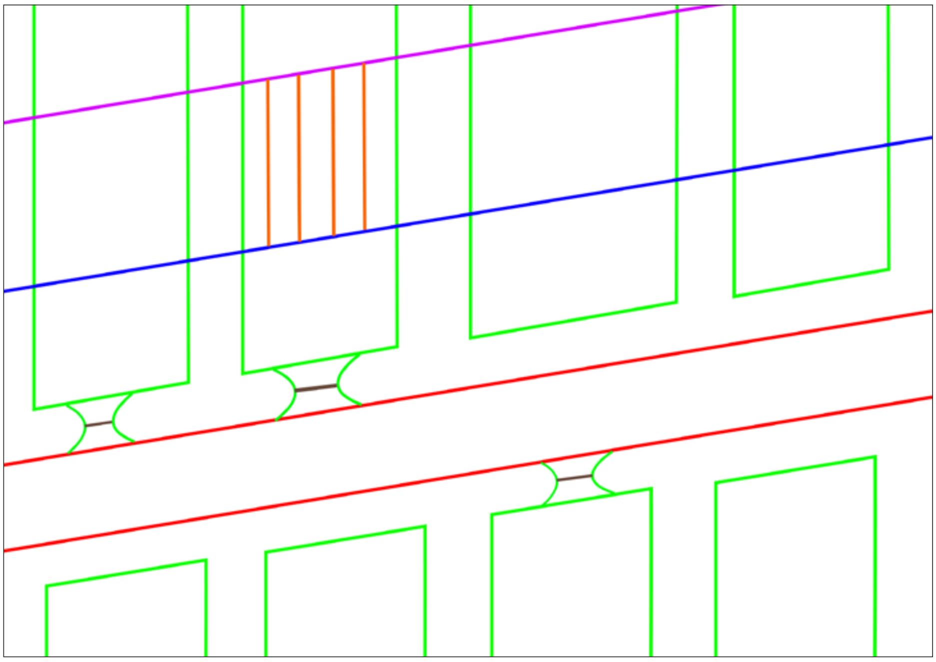
Table 2. Name, managing organization and municipality of the fifteen study sites. Sites 1-11 were sampled in 2018, Sites 12-15 were sampled in 2019.
Tabel 2. Locatienaam, beheerder en gemeente van de vijftien studielocaties. Locaties 1-11 zijn in 2018 bemonsterd en locaties 12-15 in 2019.

	Study site / onderzoeksgebied	**Manager** / terreinbeheerder	**Municipality** / gemeente
1	Meije	Natuurmonumenten	Nieuwkoop
2	Bovenlanden	Natuurmonumenten	Nieuwkoop
3	Aalkeet/Vlietlanden	Natuurmonumenten	Midden-Delfland
4	Berkenwoudse driehoek	Zuid-Hollands Landschap	Krimpenerwaard
5	Het Beijersche	Zuid-Hollands Landschap	Krimpenerwaard
6	Polder Achthoven	Zuid-Hollands Landschap	Vijfherenlanden
7	De Huibert	Zuid-Hollands Landschap	Vijfherenlanden
8	Groenzoom	Beheerderscombinatie	Lansingerland
9	Oukoop	Staatsbosbeheer	Bodegraven-Reeuwijk
10	Kagerplassen	Staatsbosbeheer	Teylingen
11	Donkse Laagten	Staatsbosbeheer	Molenlanden
12	Eemland	Natuurmonumenten	Eemnes
13	Laagjes	Natuurmonumenten	Hoekse Waard
14	Wieden-Weerribben	Natuurmonumenten	Steenwijkerland
15	Wormer- & Jisperveld	Natuurmonumenten	Wormerland

et al. 2020). We hypothesized that flower-rich grassland types would host higher abundances and larger species richness of bumblebees than grassland types poor in flowers. This means that we expect flower-rich grasslands and hay meadows to have higher bumblebee abundances and larger species richness than meadow bird grasslands. We expected road verges to be intermediate between these grassland types in terms of bumblebee abundance and species richness, due to higher management frequencies (negative effect) but absence of active fertilization (positive effect).

Methods

We studied the species richness and abundance of bumblebees in four different grassland types on fifteen different locations (table 1-2) in the Netherlands: flower-rich grasslands, hay meadows, meadow bird grasslands and road verges. First of all, we mapped flower-rich grasslands, hay meadows and meadow bird grasslands and selected eleven sites in the province of Zuid-Holland in which all three types were present within a 2 km radius. Within each study area, we randomly selected one parcel per grassland type, with help and permission of land managers. In addition, we randomly selected a road verge within 1-2 km distance of the parcels. In 2019, we selected four additional nature reserves managed by Natuurmonumenten in which each grassland type was present. We again mapped the grassland types and randomly selected parcels of each grassland type and a nearby road verge. In each of the fifteen study sites we carried out 200 m x 5 m transect walks to determine bumblebee abundance with a fixed search time of 10 minutes. Transects were cut into four 50 m sections, located at 50-100 m distance from the parcel edge and with 5-20 m distance in between sections. Parcels smaller than 25 m wide and larger than 80 m wide were not selected (figure 1). Eleven out of fifteen locations were sampled in 2018, all located in the province Zuid-Holland. The last four locations were located scattered through the west and centre of the Netherlands and were sampled in 2019. Each study site was visited twice: once in spring (May- start of June) and once in summer (July). In total, 72 transects were sampled, in good weather conditions: sunny (cloud cover <4/8), not too windy (wind speed <5 Beaufort) and temperatures above 15 °C. Bumblebees were mainly identified by experts in the field, but some specimens were collected and identified in the lab afterwards. In each transect we also determined flower abundance



1. Schematic study design. Parcel boundaries are depicted in green, roads in red, the 50-m boundary from the parcel entrance is depicted in blue, the 100-m boundary from the parcel entrance depicted in violet. Parallel transect sections of 50 m are shown in orange.
1. Schematische weergave van de studieopzet. Perceelsgrenzen zijn weergegeven in groen, wegen in rood, de 50-m grens vanaf de perceelsingang is weergegeven in blauw, de 100-m grens vanaf de perceelsingang is weergegeven in paars. De parallele secties van de 50 m-transecten zijn weergegeven in oranje.

by counting the number of inflorescences per flowering plant species in a 1 m^2 plot. Weather conditions such as temperature, cloud cover and wind speed were recorded for each transect count. More details can be found in Tanis *et al*. (2020).

Data were analysed in RStudio (version 2022.07.2; RStudio Team 2022), using Generalized Linear Mixed Models. For bumblebee abundance, data showed overdispersion in a poisson distribution and we therefore used a GLM with a negative binomial distribution (function glm.nb, package MASS) with spring abundance as dependent variable and grassland type, flower abundance, cloud cover and temperature as fixed factors. For summer bumblebee abundance we used a GLMM (function glmerMod, package lme4) with a negative binomial distribution, using grassland type, flower abundance, flower species diversity and temperature as fixed factors and area as random factor. To assess bumblebee species richness we used a GLMM (function glmerMod, package lme4) with a poisson distribution using grassland type as fixed factor and area as random factor. We selected the best models based on the AIC using function Dredge in R (Package MuMln). These models are presented.

Results

We found in total 674 bumblebees of six different species and two species complexes (table 3). *Bombus pascuorum*, *B. terrestris*-complex and *B. lapidarius* were the most commonly found bumblebee species in each grassland type. The rare *B. muscorum* was found in the area Wormer- and Jisperveld in the province of Noord-Holland in each of the grassland types (figure 2-3). The species was not recorded in this area according to the National Databank Flora and Fauna between 1960 and 2018.

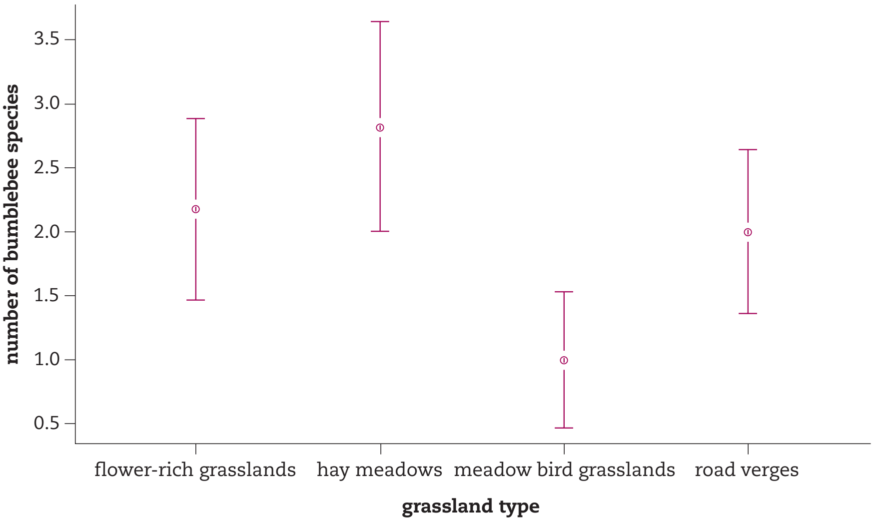
Bumblebee species richness was significantly lower in meadow bird grasslands than in flower-rich grasslands, hay meadows and road verges (table 4, figure 4). In spring, bumblebee abundances were significantly lower in meadow bird grasslands than in flower-rich grasslands, hay meadows and road verges (figure 5). Cloud cover and temperature, interestingly, both had a positive effect on spring abundances. In summer, bumblebee abundances were significantly higher in flower-rich grasslands and hay meadows than in road verges and meadow bird grasslands (figure 5). In addition, flower diversity had a positive effect on bumblebee abundances in summer and temperature had a negative effect. Flower abundance decreased in each grassland type during summer, compared to spring (figure 6).

Table 3. Bumblebee abundance in transect counts in the fifteen study sites.
Tabel 3. Talrijkheid van hommels tijdens de transecttellingen op vijftien studielocaties.

	Road verge / wegberm	**Hay meadow** / hooiland	**Flower-rich grassland** / bloemrijk grasland	**Meadow bird grassland** / weidevogelgrasland	**Total** / totaal
Bombus hortorum (Linnaeus)	10	15	1	0	26
Bombus hypnorum (Linnaeus)	3	2	2	0	7
Bombus lapidarius (Linnaeus)	26	38	28	12	104
Bombus muscorum (Linnaeus)	1	6	1	5	13
Bombus pascuorum (Scopoli)	126	152	94	16	388
Bombus pratorum (Linnaeus)	12	5	6	0	23
Bombus sylvestris (Lepeletier) / *norvegicus* (Sparre-Schneider)	0	1	0	0	1
Bombus terrestris-complex	28	46	32	6	112
Total / totaal	**206**	**265**	**164**	**39**	**674**

2. One of the sampled hay meadows, Wormer- and Jisperveld (province of Noord-Holland), in spring, habitat of *B. muscorum*. Photo: Jens Bokelaar
2. Een van de onderzochte vochtige hooilanden in het Wormer- en Jisperveld (Noord-Holland) in de lente, leefgebied van *B. muscorum*.

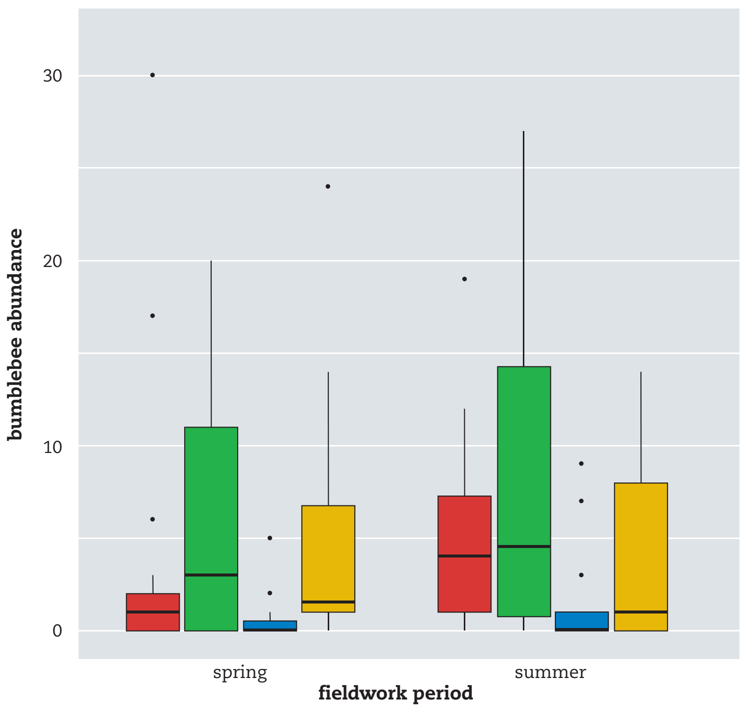
3. *Bombus muscorum* in Wormer- and Jisperveld. Photo: Jens Bokelaar
3. Moshommel *Bombus muscorum* in het Wormer- en Jisperveld.



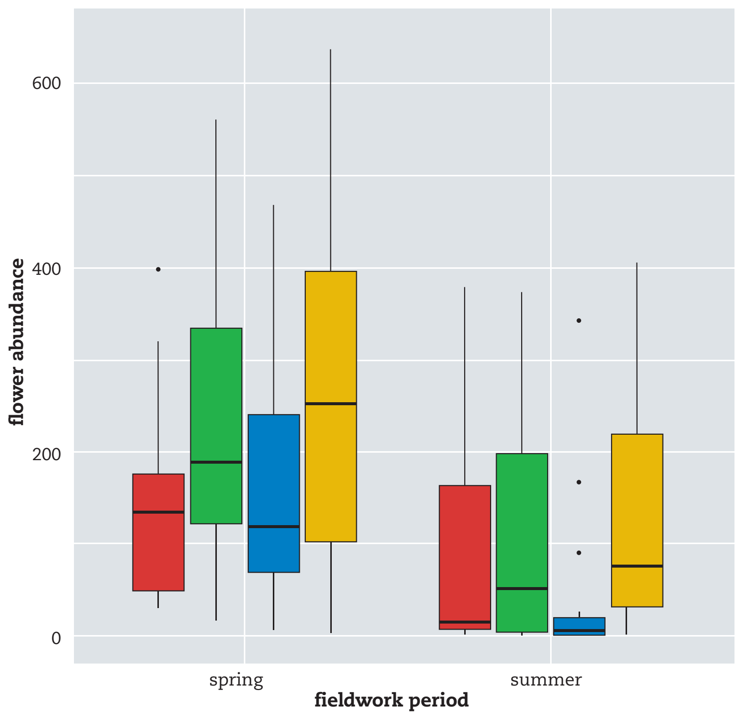
4. Bumblebee species richness per grassland type. Error bars represent means (dots) and 95% confidence intervals. Sample size: Road verges n=19, hay meadows n=17, flower rich grasslands n= 17, meadow bird grasslands n=19.
4. Hommelsoortenrijkdom per graslandtype. Foutbalken representeren de gemiddelden (punten) en de 95% betrouwbaarheidsintervallen. De streekproefgrootte per graslandtype is: bermen n=19, vochtige hooilanden n=17, flora en faunarijke graslanden n=17, vochtig weidevogelgrasland n=19.

Table 4. Model outputs. NI=Not included in this model. 'Road verges' serves as a baseline to which the other grassland types are compared and although it is included in the model it is therefore not mentioned in the table.
Tabel 4. Modeluitkomsten. NI=niet opgenomen in dit model. 'Road verges' (bermen) dient als uitgangspunt waarmee de andere graslandtypen worden vergeleken en hoewel het deel uitmaakt van het model wordt het daarom niet in de tabel genoemd.

	Model 1: Species richness / soortenrijkdom			**Model 2: Abundance spring /** talrijkheid lente			**Model 3: Abundance summer /** talrijkheid zomer		
Modeltype	GLMM			GLM			GLMM		
Distribution	Poisson			Negative Binomial			Negative Binomial		
Dependent	Bumblebee species richness			Bumblebee abundance spring			Bumblebee abundance summer		
Random	Variance	Stdev		Variance	Stdev		Variance	Stdev	
Area	0.04943	0.2223		NI			0.395	0.6285	
Fixed effects	Estimate	z-value	P	Estimate	z-value	P	Estimate	z-value	P
Intercept	0.6737	3.932	**<0.0001**	-0.8596	-1.415	0.15702	0.3850	0.675	0.49947
Type									
Flower-rich grassland	0.0722	0.311	0.756	-0.9502	-1.751	0.07993	1.1933	2.516	**0.01188**
Hay meadow	0.3180	1.440	0.15	-0.5856	-1.160	0.24595	1.1781	2.534	**0.01129**
Meadow bird grassland	-0.7082	-2.511	**0.012**	-3.0907	-4.816	**<0.0001**	-0.4560	-0.893	0.37186
Flower abundance	NI			2.3272	1.886	0.05927	0.9772	1.300	0.19361
Flower diversity	NI			NI			1.8960	2.729	**0.00635**
Cloud cover	NI			2.1632	3.221	**0.00128**	NI		
Temperature	NI			4.3844	4.768	**<0.0001**	-2.0056	-2.001	**0.04536**



5. Bumblebee abundance per season per grassland type. Boxplot shows median, first quartile, third quartile, minimum, maximum and outliers.
5. Talrijkheid van hommels per seizoen per graslandtype. Boxplot toont mediaan, eerste kwartiel, derde kwartiel, minimum, maximum en uitschieters.



6. Flower abundance (summed per transect) per season per grassland type. Boxplot shows median, first quartile, third quartile, minimum, maximum and outliers.
6. Bloemrijkdom (gesommeerd per transect) per seizoen per graslandtype. Boxplot toont mediaan, eerste kwartiel, derde kwartiel, minimum, maximum en uitschieters.

Discussion

Bumblebees in Dutch meadows

Meadow bird grasslands are home to significantly fewer bumblebees of significantly fewer species than found in flower-rich grasslands, hay meadows and road verges. Because of large scale mowing in road verges and meadow bird grasslands in June and July, bumblebee abundances in summer were higher in the (partially) unmown flower-rich grasslands and hay meadows. These results indicate that grassland management has large implications for bumblebees and that meadow bird grasslands nowadays are a poor habitat for bumblebees, compared to flower-rich grasslands and hay meadows.

There are several ecological mechanisms explaining these results. First of all, floral resource availability is a key factor influencing pollinator abundances (Biesmeijer *et al*. 2006, Goulson 2010, Goulson *et al*. 2015, Williams *et al*. 2012). In our study, flower abundances in spring tended to have a significant positive effect on bumblebee abundances (P=0.059), whereas in summer flower diversity and not flower abundance positively affected bumblebee abundances. This was especially the case in hay meadows and flower-rich grasslands. In meadow bird grasslands in spring, flowers were available, but bumblebees were still nearly absent, suggesting that spring flower abundance is not the limiting factor in this grassland type. Higher groundwater tables in these grasslands in winter and early spring, favouring meadow birds, might limit the nesting possibilities for bumblebee species nesting underground. However, this is also the case in hay meadows. The large numbers of *B. pascuorum* in hay meadows suggest another hypothesis. *Bombus pascuorum* is a species nesting on the ground, in balls of moss and grass above the surface. This nesting strategy likely makes the nests very susceptible to mowing. In hay meadows, mowing traditionally takes place in August or early September. At that time, a large proportion of *B. pascuorum* colonies have already completed their cycle and mowing hay meadows generally does less harm to bumblebees. In meadow bird grasslands however, mowing takes place from early June onwards. Afterwards, the grasslands are fertilized with slurry and/or solid manure. This nitrogen gift stimulates productive grasses to grow and makes it possible for the (tenant) farmers to have some roughage harvest from this set-aside grassland. However, both mowing in June and application of slurry damages surface nests. Postponing the first mowing cut until August in meadow bird grasslands will likely not solve the entire problem: these grasslands are increasingly nutrient rich and taking this measure may result in too dense, stiff and flattened vegetations, which are unsuitable for both meadow birds, bumblebees and farmers. The best way to improve meadow bird grasslands for bumblebees and meadow birds (Breeuwer *et al*. 2009) is to strongly reduce the nitrogen input to (almost) zero kilograms of nitrogen per hectare. This will reduce the vegetation production, open the vegetation structure and increase the establishment opportunities for herbs, thereby increasing the availability of flowers in these grasslands (Schippers *et al*. 2012).

Management improvements

In the absence of grazing by large herbivores, mowing is a necessary management action in most of the West European grassland systems (Vera 2000, Wallis de Vries 1995): it prevents the grassland from developing into forest. However, mowing also has negative effects on insects (Morris 2000): it leads to direct mortality caused by cutting the vegetation and local soil compaction caused by mowing machines (Humbert *et al*. 2009, Wallis de Vries & Knotters 2000). Indirectly, mowing reduces food availability, microclimatic heterogeneity and reproductive habitat (Lebau *et al*. 2015). Two factors can mitigate the effects of mowing to insects: timing in the year and scale. Delayed mowing can have beneficial effects on insects such as bumblebees, since it extends the availability of food, shelter and reproductive habitat (Bonari *et al*. 2017, Buri *et al*. 2013, Lye *et al*. 2009, Stip & Van Grunsven 2018, Stip & Van Swaay 2020). However, as stated before, in highly productive grassland systems it is a better conservation strategy to first reduce nitrogen inputs and only after a substantial reduction in vegetation production (up till six tons of dry matter per hectare; Schippers *et al*. 2012) delayed mowing till July or August will be possible. The second factor reducing the impact of mowing on insects is scale. Leaving parts of the vegetation unmown (known as phased mowing or partial mowing) will increase the constancy of food availability – which is highly important to bumblebees – and permanently provide shelter and reproduction habitat (Bonari *et al*. 2017, Buri *et al*. 2013, Lebau *et al*. 2015,). Small-scale grassland management based on local terrain elements, such as sinus mowing (Couckuyt 2015, Stip & Van Swaay 2020) can have beneficial effects on insects in general and likely also on bumblebees. In each of the four studied grassland types, grassland management that takes timing and scale into account, will improve conditions for bumblebees.

The results of our study indicate that hay meadows and flower-rich grasslands can be suitable habitat for bumblebees, by providing both food and nest sites. Road verges also have a high potential, depending on scale and timing of mowing. In meadow bird grasslands it is important to first make the choice for nature: reduce the input of nitrogen, eventually combined with increased water tables (Breeuwer *et al*. 2009). This will only be possible when farmers will get more than cost-effective reimbursements, allowing them to 'lose' on cattle forage quality but still have a farming income. As a result of the measures, vegetation heterogeneity and flower richness in meadow bird grasslands will increase, creating a suitable habitat for both meadow birds and bumblebees (Schekkerman *et al*. 2008). Creating a better future for bumblebees and other fauna in moderately nutrient-rich grassland systems starts with centring on the ecology of the species that inhabit the system while also prioritizing the socio-economic needs of the human users of the grassland systems.

Acknowledgements

We thank Ninouk Vermeer, Sietse Kleinjan, René Garskamp (Zuid-Hollands Landschap), Tim van den Broek, Martijn van Schie, Rosalie Martens (Natuurmonumenten), Cor Noorman (Groenzoom), Nico de Bruijn and Casper Zuyderduin (Staatsbosbeheer) for their help and cooperation in field work permissions. We are grateful to Martijn van Schie and Tim van den Broek for discussing the management implications of this study. We also thank Martijn Kos and an anonymous reviewer for their feedback, which significantly improved this article. This project was funded by WWF-NL Biodiversity fund, Fonds Diorapthe, Fonds Zabawas and Prins Bernhard Cultuurfonds.

References

Biesmeijer JC, Roberts SPM, Reemer M, Ohlemüller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J & Kunin WE 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 313: 351-354.

BIJ12 2020. Landelijke beheertypenkaart. Beschikbaar op: www.bij12.nl/onderwerpen/natuur-en-landschap/productencatalogus/kaarten/landelijke-beheertypenkaart [consulted 14 November 2020].

Breeuwer A, Berendse F, Willems F, Foppen R, Teunissen W, Schekkerman H & Goedhart P 2009. Do meadow birds profit from agri-environment schemes in Dutch agricultural landscapes? Biological Conservation 142: 2949-2953.

Bonari G, Fajmon K, Malenovský I, Zelený D, Holuša J, Jongepierová I, Kočárek P, Konvička O, Uřičář J & Chytrý M 2017. Management of semi-natural grasslands benefiting both plant and insect diversity: The importance of heterogeneity and tradition. Agriculture, Ecosystems & Environment 246: 243-252.

Buri P, Arlettaz R & Humbert JY 2013. Delaying mowing and leaving uncut refuges boosts orthopterans in extensively managed meadows: Evidence drawn from field-scale experimentation. Agriculture, Ecosystems & Environment 181: 22-30.

CBS 2016. Voor het eerst in 9 jaar meer blijvend grassland. Available at: www.cbs.nl/nl-nl/nieuws/2016/21/voor-het-eerst-in-9-jaar-meer-blijvend-grasland [consulted 14 November 2020].

Couckuyt J 2015. Sinusbeheer: maaibeheer op maat van dagvlinders en insecten. VVE WG Dagvlinders. Persoonlijk onderzoek 2015-2.

Dupont YL, Damgaard C & Simonsen V 2011. Quantitative historical change in bumblebee (*Bombus* spp.) assemblages of red clover fields. PLoS ONE 6(9): e25172.

Goulson D, Hanley ME, Darvill B, Ellis JS & Knight ME 2005. Causes of rarity in bumblebees. Biological Conservation 122: 1-8.

Goulson D 2010. Bumblebees. Behaviour, ecology and conservation. Second edition. Oxford University Press.

Goulson D, Nicholls E, Botías C & Rotheray EL 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 347: 1255957.

Humbert JY, Ghazoul J & Walter T 2009. Meadow harvesting techniques and their impacts on field fauna. Agriculture, Ecosystems & Environment 130: 1-8.

Kleijn D & Raemakers IP 2012. Waardplant-voorkeur van hommels: terugkijken in de tijd. Entomologische Berichten 72: 21-35.
Lebau J, Wesselingh RA & Van Dyck H 2015. Butterfly density and behaviour in uncut hay meadow strips: behavioural ecological consequences of an agri-environmental scheme. Plos One DOI:10.1371/journal.pone.0134945.
Morris MG 2000. The effects of structure and its dynamics on the ecology and conservation of arthropods in British grasslands. Biological Conservation 95: 129-142.
Potts SG, Woodcock BA, Roberts SPM, Tscheulin T, Pilgrim ES, Brown VK & Tallowin JR 2009. Enhancing pollinator biodiversity in intensive grasslands. Journal of Applied Ecology 46: 369-379.
Reemer M 2018. Basisrapport voor de Rode Lijst Bijen. Rapport EIS2018-06, EIS Kenniscentrum Insecten.
RStudio Team 2022. RStudio: Integrated development for R. RStudio, PBC, Boston, MA URL, www.rstudio.com.
Schekkerman H, Teunissen W & Oosterveld E 2008. The effect of 'mosaic management' on the demography of black-tailed godwit *Limosa limosa* on farmland. Journal of Applied Ecology 45: 1067-1075.
Schippers W, Bax I & Gardenier M 2012. Ontwikkelen van kruidenrijk grasland. Aardewerk Advies.
Stip A & Van Grunsven RHA 2018. Beheermaatregelen voor insecten in graslanden in midden Friesland. Rapport VS2018.018, De Vlinderstichting.
Stip A & Van Swaay CAM 2020. Effecten van sinusbeheer op biodiversiteit in Noord-Brabant. Rapport VS2020.028, De Vlinderstichting.
Stip A, Slikboer L, Tanis M & Bokelaar J 2020. Hommels in Nederlandse graslanden – resultaten van Weide Hommelrijk. Rapport VS2020.033, De Vlinderstichting / Rapport 2020-23 EIS Kenniscentrum Insecten.
Tanis MF, Marshal L, Biesmeijer JC & Van Kolfschoten L 2020. Grassland management for meadow birds in the Netherlands is unfavourable to pollinators. Basic and Applied Ecology 43: 52-63.
Timberlake TP, Vaughan IP & J Memmott J 2019. Phenology of farmland floral resources reveals seasonal gaps in nectar availability for bumblebees. Journal of Applied Ecology 56: 1585-1596.
Vera FWM 2000. Grazing ecology and forest history. CABI Publishing.
Wallis de Vries MF 1995. Large Herbivores and the Design of Large-Scale Nature Reserves in Western Europe. Conservation Biology 9: 25-33.
Wallis de Vries MF & Knotters JC 2000. Effecten van gefaseerd maaibeheer op de ongewervelde fauna van graslanden. De Levende Natuur 101: 37-40.
Westrich P 2018. Die Wildbienen Deutschlands. Eugen Ulmer.
Williams NM, Regetz J & Kremen C 2012. Landscape-scale resources promote colony growth but not reproductive performance of bumble bees. Ecology 93: 1049-1058.
Weeda E, Schaminée JHJ & Van Duuren L 2002. Atlas van plantengemeenschappen in Nederland. Deel 2: Graslanden, zomen en droge heiden. KNNV Uitgeverij.

Accepted: September 17, 2023

Samenvatting

Zijn hommels succesvol in Nederlandse weidevogelreservaten (Hymenoptera: Apidae)?
Bloemrijke graslanden vormen een belangrijk habitat voor hommels. Omdat bloemrijke graslanden steeds schaarser worden in onze landschappen staan veel hommelsoorten onder druk. In Nederland is momenteel nog ruim 205.000 hectare matig voedselrijk grasland aanwezig, maar over de betekenis voor hommels is weinig bekend. Daarom hebben wij in 2018 en 2019 de soortenrijkdom en talrijkheid van hommels onderzocht in vier verschillende graslandtypen op vijftien locaties op veen- en kleibodems in Nederland. Het betrof wegbermen en drie graslandtypen die bekend zijn uit het Subsidiestelsel Natuur en Landschap, te weten flora en faunarijk grasland (N12.02), vochtig hooiland (N10.02) en vochtig weidevogelgrasland (N13.01). Wij vonden in totaal 674 hommels van acht verschillende soorten. De talrijkheid en soortenrijkdom van hommels was significant lager in vochtige weidevogelgraslanden dan in flora- en faunarijke graslanden, vochtige hooilanden en wegbermen. Dit werd voornamelijk veroorzaakt door een tekort aan bloemen in weidevogelgraslanden, als gevolg van hoge stikstofmestgiften en grootschalig maaibeheer aan het einde van het broedseizoen voor weidevogels. In dit artikel geven we suggesties om het graslandbeheer voor hommels te verbeteren.

Anthonie Stip
Dutch Butterfly Conservation / De Vlinderstichting
Wageningen, the Netherlands
Anthonie.stip@vlinderstichting.nl

Marco Tanis, Linde Slikboer
EIS Kenniscentrum Insecten
Leiden, the Netherlands

Jens Bokelaar
Dutch Butterfly Conservation / De Vlinderstichting
Wageningen, the Netherlands