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Coláiste na hOllscoile Corcaigh

1 **The effect of management practices on bumblebee densities in hedgerow and grassland**
2 **habitats**

3

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11

12 **Running head:** Management type and bumblebee density

13

14

15 **Abstract**

16 Large-scale declines in pollinator species are a concern at present. Such declines have been
17 attributed to a range of factors that act in tandem, rather than in isolation. Some of the most
18 pervasive factors affecting pollinator populations are habitat loss and degradation, which
19 results in the loss of floral resources, nesting sites and landscape connectivity. Intensification
20 of agriculture and urbanisation are two major causes of such habitat alterations. Hedgerows
21 and grasslands are two vital habitats for pollinators in European landscapes. When managed
22 appropriately, these habitats may provide abundant floral resources and nesting opportunities,
23 as well as connectivity between habitats in a fragmented landscape. This study examined the
24 effects that management practices of hedgerows and grasslands may have on bumblebee
25 species, an important group of wild pollinators. Bumblebee abundance was recorded using
26 transect walks in managed and unmanaged sites, including both hedgerows and grasslands.
27 Greater densities of bumblebees were found in unmanaged grasslands in comparison to
28 managed grasslands. Unmanaged hedgerows were also found to have a greater density of
29 bumblebees than managed hedgerows. These results indicate that sites which are less
30 intensively managed provide a more suitable habitat for bumblebees. Therefore, our study
31 underlines the importance of a) enforcing restrictions on hedge-cutting, and b) reducing the
32 management intensity of grasslands to provide adequate habitat for pollinators.

33 **Keywords:** bumblebees; pollinators; management; anthropogenic disturbance; hedgerow;
34 grassland; floral diversity.

35

36

37 **Introduction**

38 Animal (especially insect) pollination is necessary for the pollination of important crop species
39 and wild plants, and thus is an important ecosystem service (Klein et al., 2007; Gallai et al.,
40 2009; Ollerton et al., 2011). Indeed, the majority of the world's flowering plants are dependent
41 on insects for their pollination (Ollerton et al., 2011) and further large-scale declines in
42 pollinators could lead to a nutritional impoverishment of the human diet (Eilers et al., 2011).

43 Large-scale declines in pollinating insects have occurred across the globe (Williams &
44 Osborne, 2009; Winfree et al., 2009; however, see Ghazoul, 2005). Regionally, such declines
45 are particularly apparent in North America (Colla & Packer, 2008; Grixti et al., 2009; Cameron
46 et al., 2011; Burkle et al., 2013) and Europe (Steffan-Dewenter et al., 2005; Biesmeijer et al.,
47 2006; Kosior et al., 2007; Goulson et al., 2008; Potts et al., 2010a). Several causes have been
48 proposed for such pollinator declines (Potts et al., 2010b), including land use change (Brown
49 & Paxton, 2009; Winfree et al., 2009), agrochemicals (Alston et al., 2007; Holzschuh et al.,
50 2008; Brittain et al., 2010), pathogens (Colla et al., 2006; Rosenkranz et al., 2010), alien species
51 (Stout & Morales, 2009), and climate change (Williams et al., 2007).

52 Land use is probably the most important driver of bee declines (Brown & Paxton, 2009;
53 Winfree et al., 2009). Although some alterations to habitat (e.g. urbanisation) may have
54 positive effects on bee diversity and local abundance (Cane et al., 2006; Carré et al., 2009),
55 changes in land use normally lead to the loss or degradation of suitable pollinator habitat, thus
56 limiting their floral resources and potential nesting sites. Similar to global declines, natural and
57 semi-natural habitat loss plays a huge role in the decline of pollinators in Ireland (Fitzpatrick
58 et al., 2007; Fitzpatrick & Stout, 2015). The loss and changing nature of grasslands in Ireland
59 is likely a major driver in pollinator losses, as well as shifts or contractions in their range
60 (Fitzpatrick et al., 2007).

61 Twenty-one species of bumblebees have been recorded in Ireland. Six of these species are
62 considered ‘threatened’, with a further 3 species being ‘near threatened’ (Fitzpatrick & Stout,
63 2015). The four bumblebee species that have declined the most in Ireland (*Bombus*
64 *distinguendus*, *B. ruderarius*, *B. sylvarum* and *B. muscorum*), are all later emerging species
65 associated with open grassland habitats (Fitzpatrick et al., 2007). Declines in these ecologically
66 similar species are likely a result of the shift in the past 30 years from hay production to silage
67 production. This shift in production decreases the amount of wild flowers occurring in
68 meadows throughout the summer, when bees are more active (Vickery et al., 2001).

69 Many bumblebee species in Ireland have become rare in the eastern regions of their original
70 ranges; this is likely a result of urbanisation and increasingly intensive agricultural practices in
71 the east of the country (Santorum & Breen, 2005). Conversely, the midlands and western
72 regions of Ireland have retained much of their grassland habitats and thus bumblebee diversity
73 (Fitzpatrick et al., 2007).

74 Hedgerows are an important habitat for pollinators (Klein et al., 2007; Garibaldi et al., 2014;
75 Goulson et al., 2015). Hedgerows provide food resources and safe nesting sites for pollinators,
76 as well as acting as wildlife corridors, linking other suitable habitats (Stanley & Stout, 2013;
77 Fitzpatrick & Stout, 2015). Hedgerows and uncropped field margins in close association are of
78 particular benefit to pollinator populations in Irish agricultural landscapes (Ghazoul, 2005;
79 Stanley & Stout, 2013).

80 As hedgerows and grasslands are important habitats for pollinator species, finding an
81 appropriate management regime for these two habitat types is imperative to the persistence of
82 sustainable populations of bumblebee species in Ireland. Both grasslands and hedgerows can
83 be found in the Irish landscape in two distinct forms: managed and unmanaged. Our study seeks
84 to establish which of these two management types in hedgerow and grassland habitats hosts a
85 greater abundance of bumblebees. We predicted that unmanaged habitats, possibly having a

86 greater floral diversity and abundance than managed habitats, will sustain higher bumblebee
87 densities.

88

89 **Materials and methods**

90 *Study System*

91 Sixty study sites were selected in a rural area of County Carlow, in South East Ireland. All sites
92 were contained within a triangular area of 19.76 km² of agricultural landscape. The greatest
93 distance between two sites was 6.8 km. These 60 sites were selected based on their habitat type
94 (hedgerow or grassland), and their management type (managed or unmanaged), resulting in 15
95 sites for each of the following four categories: managed hedgerow, unmanaged hedgerow,
96 managed grassland, and unmanaged grassland. Managed hedgerows were characterised by a
97 very uniform shape along their 100 m stretch. Very little, if any, vegetation in these managed
98 hedgerows protruded out from the hedgerow. The grassy verge beneath managed hedgerow
99 was generally mowed. Unmanaged hedgerows were less uniform in their shape in comparison
100 to managed hedgerows; vegetation height and width often varied, protruding out from the
101 hedge in areas, and no visible signs of recent physical management could be seen. Managed
102 grasslands were within parks, gardens, and road verges, and were frequently mowed, in many
103 cases once or twice every week. Unmanaged grasslands included undisturbed patches in
104 farmlands, and abandoned areas in sports complexes and former construction sites. Areas that
105 are purposely left idle and cultivated on occasion throughout the summer for hay or silage
106 production were not included in our study. Use of herbicides was not observed in any of the
107 sites. Each of the 60 sites was sampled four times (for a total of 240 transect walks, as explained
108 below), on random occasions throughout the sampling period between 11th June and 2nd
109 September 2017. Each of the four visits to a particular site took place at least one week apart.
110 Three of these transects were discounted due to an alteration of management type taking place

111 during the study. All transects were performed between the hours of 10 a.m. and 5 p.m., when
112 bumblebees are most active. No transects were performed during or directly following periods
113 of rain.

114 Prior to the study, we identified all sites, recorded their GPS locations, and measured the length
115 (of hedgerows) or area (of grasslands). Floral diversity (as the number of different flowering
116 plant species) at each site was recorded at the beginning of the study, prior to the first sampling
117 taking place. If a new plant variety came into flower on subsequent visits to a site, this was
118 added to the list of flowering plants for that site. The temperature ($^{\circ}\text{C}$) and wind speed ($\text{km}\cdot\text{h}^{-1}$)
119 was logged prior to performing a transect walk at each site using a smartphone weather
120 application (AccuWeather GPS Weather Widget).

121 The method of sampling differed between hedgerows and grasslands. In the case of hedgerows,
122 a fixed 100-metre stretch of hedgerow was walked at a constant speed while scanning for
123 bumblebees. In the case of grasslands, three repeated transect walks or ‘laps’ were carried out
124 one after the other, due to the small size of some of the selected grasslands (range: 28 to 555
125 m^2 ; mean \pm s.d. for unmanaged grasslands: $150.5 \pm 96.74 \text{ m}^2$; mean \pm s.d. for managed
126 grasslands: $207.7 \pm 135.16 \text{ m}^2$; t-test between areas of managed and unmanaged grasslands: t_{28}
127 $= -1.15$, $p = 0.26$). These three repeated laps were performed within the grassland at a constant
128 distance approximately 2 m from the site’s outer perimeter. For each visit, the number of
129 bumblebees present in a site was the maximum recorded over the three laps.

130 For both habitat types, we recorded bumblebees that were both landed on flowers and flying.
131 We recorded many more landed than flying bumblebees (total number of bumblebees recorded
132 in hedgerows: landed = 479 bumblebees, flying = 36 bumblebees; total number of bumblebees
133 recorded in grasslands: landed = 273 bumblebees, flying = 44 bumblebees). Consequently,
134 analyses considering only landed bumblebees or all bumblebees (i.e. landed plus flying

135 bumblebees) offered qualitatively similar results. We only present results for the analyses
136 considering all bumblebees recorded. Bumblebee species were not identified in this study.

137

138 *Statistical Analyses*

139 We conducted our statistical analyses using R, version 3.4.2 (R Core Team, 2017). We set
140 significance at $p < 0.05$. As the sampling method of hedgerows and grasslands was dissimilar,
141 data for both types of habitat were analysed separately.

142 We determined if the number of bumblebees differed between managed and unmanaged
143 hedgerows implementing a generalised linear mixed model (GLMM), with the total number of
144 bumblebees as the response; type of management, wind, and temperature as fixed factors; and
145 site as a random factor (to account for the fact that we sampled each site on four different
146 occasions). We fitted a GLMM with a negative binomial distribution and log link function
147 using the `glmer.nb` function in the package `lme4`.

148 To determine if the number of bumblebees differed between managed and unmanaged
149 grasslands, we fitted a GLMM with a Poisson distribution and log link using the function `glmer`
150 in the package `lme4`. We used the maximum number of bumblebees observed over three
151 consecutive laps as the response; type of management, wind, and temperature as fixed factors;
152 site as a random factor; and area as an offset (to account for the fact that different grasslands
153 had different areas).

154 To determine the effect of floral diversity on bumblebee abundance in managed and
155 unmanaged habitats we implemented general linear models (GLM) using the function `lm` in
156 the package `stats`, with the average of bumblebees recorded during the four visits to each site
157 as the response (log transformed); and type of management and floral diversity as the fixed
158 factors, including their interaction.

159

160 **Results**

161 We found more bumblebees in unmanaged hedgerows (mean \pm standard deviation: 5.42 ± 5.97
162 bumblebees per 100 m hedgerow) than in managed hedgerows (3.25 ± 3.64 bumblebees per
163 100 m hedgerow; GLMM: $z = 2.06$, $p = 0.039$; Fig. 1A). Wind and temperature did not have
164 an effect on the number of bumblebees recorded in hedgerows ($p > 0.2$ for both factors). Floral
165 diversity did not have a significant effect on the number of bumblebees found in hedgerows
166 overall ($t = -0.63$, $p = 0.53$) or depending on the type of management (interaction: $t = 1.26$, $p =$
167 0.22). This is not surprising, as floral diversity did not differ between managed hedgerows
168 (mean \pm standard deviation: 5.67 ± 1.8 species) and unmanaged hedgerows (5.87 ± 1.69
169 species; t -test: $t_{28} = 0.31$, $p = 0.76$). Unfortunately, we did not measure or estimate floral
170 abundance.

171 We also found more bumblebees in unmanaged grasslands (mean \pm standard deviation: 129.28
172 ± 129.54 bumblebees per hectare) than in managed grasslands (30.62 ± 32.08 bumblebees per
173 hectare; GLMM: $z = 3.81$, $p = 0.0001$; Fig. 1B). Wind and temperature did not have an effect
174 on the number of bumblebees recorded at grasslands ($p > 0.05$ for both factors). Floral diversity
175 did not have a significant effect on the number of bumblebees found in grasslands overall ($t =$
176 0.63 , $p = 0.54$) or depending on the type of management (interaction: $t = 0.66$, $p = 0.51$). Floral
177 diversity did not differ between managed grasslands (mean \pm standard deviation: 5.13 ± 2.13
178 species) and unmanaged grasslands (5.93 ± 1.91 species; t -test: $t_{28} = 1.08$, $p = 0.29$).

179

180 **Discussion**

181 Our results indicate that management of both hedgerows and grasslands can have a detrimental
182 effect on bumblebee abundances. The influence of management on bumblebee densities was
183 less apparent in hedgerows than in grasslands. One factor that can explain this finding is that
184 hedgerows had not been managed as recently, or as frequently as grasslands over the sampling

185 period (June 11th to September 2nd). This is due to the fact that the cutting of hedgerows is
186 nationally prohibited between March 1st and August 31st; although some hedgerows may still
187 be cut back under certain circumstances. Consequently, the first hedgerow transect of the study
188 was walked, potentially, three months or more after the previous cut had taken place in
189 February. This would have allowed plants in managed hedgerows an extended period to set
190 seed and flower undisturbed, from early spring. This contrasts greatly to managed grassland
191 habitats, which were often cut weekly and throughout the period of sampling. Although our
192 aim was not to compare directly bumblebee densities between hedgerows and grasslands, we
193 found that bumblebee densities were clearly higher in the linear habitat (hedgerow) than in the
194 non-linear habitat (grassland), as previously shown (Osborne et al., 2008).

195 We found no difference in floral diversity between managed and unmanaged habitats.
196 However, a greater abundance of floral resources is likely to make a site more valuable to
197 bumblebees, as opposed to a site with fewer plants but with a higher variety of plant species.
198 In fact, bumblebees have been documented to forage on a narrow range of flowering plant
199 species (Santorum & Breen, 2005), so floral diversity may not be a particularly limiting factor
200 to bumblebees. Although we did not measure floral abundance, this is likely to be greater in
201 unmanaged habitats than in those that are routinely or intensively managed.

202 Managed grassland sites in this study were largely confined to roadsides, gardens or public
203 spaces. In such locations, the nature of management is both frequent and intense, especially in
204 the summer months when mowing is more common. Regular mowing will result in flowering
205 plants being cut back; often at times when they are most useful to wild pollinators. Conversely,
206 not managing grasslands will allow the available flora in the seed bank to set seed and flower
207 undisturbed. As a result, flowering plants in unmanaged grasslands will likely be more
208 abundant, and of greater value to bumblebees for a longer period of time than those in managed

209 grasslands. Thus, unmanaged grasslands may be more reliable forage sites than managed
210 grasslands.

211 A greater proportion of edge habitat will provide more benefits to wild pollinators in the form
212 of floral resources and potential nesting sites. Edge habitat of grasslands and croplands is often
213 much richer in floral resources than central areas (Gabriel & Tschardtke, 2007; Stanley &
214 Stout, 2013). However, a few plant species abundant in central areas of grasslands (e.g.
215 dandelions and clover) may also be highly important to pollinators during spring.

216 Neither of the assessed environmental conditions (temperature and wind speed) seemed to
217 influence bumblebee densities to a great extent in this study. The summer months in Ireland
218 are defined by a narrow range of temperatures. Transect walks from this study were carried out
219 at temperatures between 14 °C – 25 °C. The low variability in temperature in Ireland likely
220 means bumblebees can be active throughout the summer, independent of temperature on a
221 given day. Hence, it is not surprising that we found no effect of temperature on bumblebee
222 densities.

223 Wind speed was more variable than temperature (9 km*h⁻¹ – 30 km*h⁻¹). Although bumblebees
224 may be less willing to fly greater distances, or with greater frequency, during periods of high
225 winds, the range of wind speeds that we observed may not have been sufficient to significantly
226 affect bumblebee behaviour. In any case, wind speed can be highly changeable during a day,
227 and the number of bumblebees observed at any time may be determined by the current wind
228 conditions.

229 In conclusion, here we show that greater densities of bumblebees are found in unmanaged
230 grasslands and hedgerows than in managed habitats. Floral abundance may be a better measure
231 of a habitat's suitability to bumblebees than floral diversity, and this should be a priority
232 measurement in future studies of a similar nature. A recommendation derived from our findings
233 is for management intensity and frequency to be reduced in order to make grasslands more

234 hospitable for wild bumblebees. During times of peak bumblebee activity, management
235 practices of grasslands should be limited as far as possible, to increase the availability of forage
236 sources. Similarly, well-timed management of hedgerows, when necessary, should be
237 implemented. Although management of hedgerows in February may not have had a great effect
238 on bumblebees in mid-late summer (this study's sampling period), it may affect the floral
239 resources and nesting sites available to them in spring, earlier in their life cycle (Fitzpatrick &
240 Stout, 2015; Goulson et al., 2015). It is proposed that the period in which hedge-cutting is
241 permitted (September – March) should not be extended; and further study should take place in
242 spring to examine the effect of hedgerow management on these important pollinators earlier in
243 the year.

244

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247

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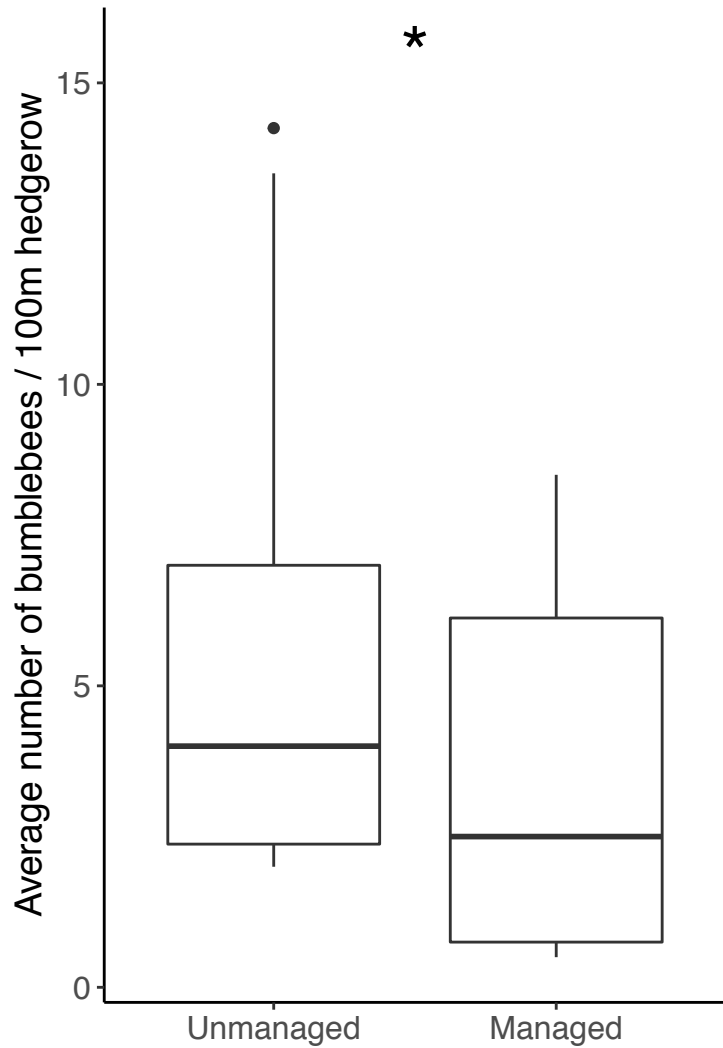
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348 **Figure legends**

349 **Fig. 1.** Bumblebee abundance recorded in hedgerows (A) and grasslands (B) that were
350 managed or unmanaged. Values represent the average of bees recorded during four different
351 visits to each site. For each boxplot, the bar within each box represents the median, each box
352 represents the first and third quartiles (or 25th and 75th percentiles), the two whiskers represent
353 the maximum values that are within 1.5 * IQR of the box (where IQR or inter-quartile range is
354 the distance between the first and third quartiles), and points beyond the whiskers represent
355 outliers. Significant differences between managed and unmanaged habitats were obtained
356 using generalised linear mixed models (* denotes $p < 0.05$; *** denotes $p < 0.0005$).

357

(A) Hedgerows



(B) Grasslands

