PLANT–POLLINATOR INTERACTIONS WITHIN A SEED PRODUCTION AREA FOR NATIVE GRASSLAND RESTORATION

Nina White[1,2*], Paul Gibson-Roy[3] and James M. Cook[1]

[1] Hawkesbury Institute for the Environment, Western Sydney University, NSW, Australia

[2] School of Biosciences, Cardiff University, Cardiff, UK

[3] Greening Australia, NSW, Australia

*Corresponding author: WhiteN8@cardiff.ac.uk

Keywords: Grassland restoration, native grassland, pollinators, plant-pollinator interactions

Introduction

Lowland temperate grasslands are an endangered native ecosystem in south-eastern Australia (Williams et al., 2015). The loss of native habitat is widely understood to negatively impact insect communities through habitat fragmentation and the loss or reduction of plant species diversity, floral resources and nesting sites (Biesmeijer et al., 2006). Declines in insect biodiversity, and in particular the loss of pollinator populations, are of great concern where this impacts on the reproductive success of many native and crop plant species.

Grassland restoration in Australia aims to reconstruct species rich and functional native grasslands, using dedicated seed production areas (SPAs) to grow native seed crops. Growers typically note influxes of invertebrates to SPAs, yet there have been no formal studies to quantify or understand these observations. As insects are the major pollinators of grassland forbs and shrubs, it is surprising that this interaction remains largely unexplored in south-eastern Australia (Williams et al., 2015). A key restoration question posed by Gibson-Roy and Delpratt (2015) is: which plants, or combinations of plants, are important to include in restoration seed mixes? Any information on the abundance or diversity of insect pollinator species visiting specific grassland plant species in a SPA could be crucial to justifying, assessing, and tailoring future restoration projects to have maximum benefit to pollinators.

This study assessed the composition and diversity of the insect pollinator community visiting the Greening Australia SPA in Richmond, NSW. Eleven plant species, each exhibiting strong flowering attributes, were monitored through observational surveys of flower visitors.

Methods

Study area and plant species

The study was carried out in a Greening Australia SPA located in Richmond, NSW. The SPA is comprised of over 100 'cells', each containing one species of ground-layer plant native to the Cumberland Plain. Eleven plant species were surveyed, chosen for exhibiting strong flowering attributes: *Calotis cuneifolia, Calotis lappulacea, Chrysocephalum apiculatum, Geranium homeanum, Goodenia hederacea, Hibbertia diffusa, Linum marginale, Ranunculus lappaceus, Scaevola albida, Thysanotus tuberosus* and *Wahlenbergia communis.*

Visual observation surveys

Visual observation surveys were carried out from 01/11/15 to 17/02/16. Observations were taken on dry, warm (> 21°C) days with low winds. A time period of 08:00 – 17:00 was covered to give the most representative sample of insects at the SPA. Each cell contained three linear transects of 5 m. Observations were carried out for six minutes per cell, by walking for two minutes in one direction along each of the three transects in the cell. Insects seen on a flower were recorded to the following taxonomic resolution: small bee (< 5 mm), medium bee (5 mm – 10 mm), large bee (> 10 mm), wasp, hoverfly, Lepidoptera, other Diptera, Hemiptera, and Coleoptera. This resolution was chosen for being the most reliably accurate measure of live flying insects observed from a couple of metres distance in the field.

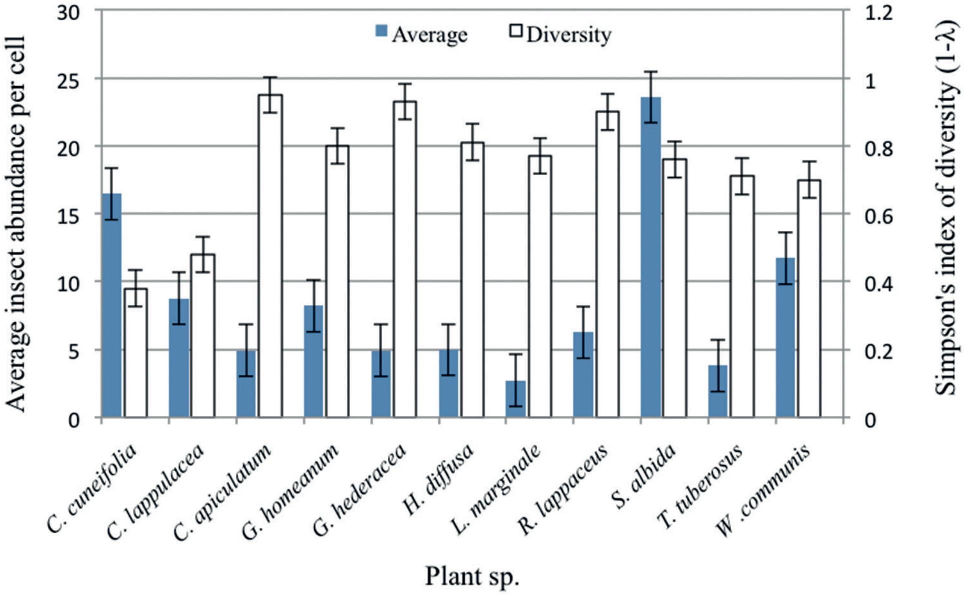
Statistical analyses

A PERMANOVA was used to identify changes in the insect community composition between plant species. A Kruskal-Wallis rank sum test was performed to investigate the differences in abundance of individual insect groups between plant species, as the data could not be transformed to fit the assumptions of an ANOVA. To investigate pairwise comparisons of insect abundances between plant species, a kruskalmc post hoc test was used from the pgirmess R package (Giraudoux,2016).

Results

Average flower-visiting insect (FVI) abundance per cell, and diversity were calculated for each of the eleven study flower species (Figure 1). Diversity was calculated using Simpson's index (SI) of diversity (Simpson, 1949). The plant species with notably high average FVI abundance of >10 individuals were *S. albida, C. cuneifolia* and *W. communis*. All other flower species had an average FVI abundance in the range of 2.70 – 8.76 individuals per cell. The flower species that supported a notably diverse pollinator community of SI >0.90 were *C. apiculatum, G. hederacea,* and *R. lappaceus*. All other plants supported a FVI community that ranked in the top third of the diversity index (SI >0.70), except for species from the *Calotis* genus*, C. cuneifolia* and *C. lappulacea*, which had a relatively low FVI diversity of SI <0.49 compared with the other nine plant species.

Figure 1.
The average abundance of all insect groups combined for each flower species, and the corresponding diversity rating from Simpson's index (SI). Dark blue = average insect abundance per cell, light blue = SI rating. Error bars = standard error.

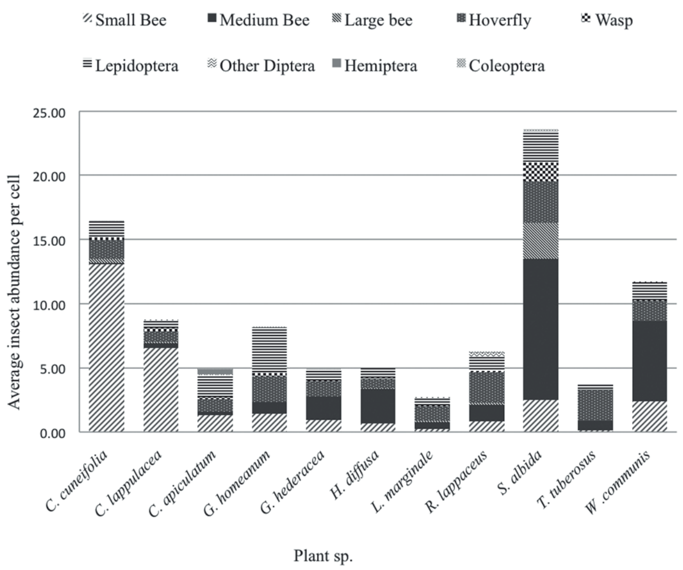


The abundances of small, medium and large bees, hoverflies, wasps and Lepidoptera varied significantly across all flower species (PERMANOVA, p = 0.001, Table 1). Small bee abundance was greatest on *C. cuneifolia* and *C. lappulacea* flowers compared with all other plant species (Figure 2, Table 2). Medium bees were significantly more abundant on *S. albida* and *W. communis.* For large bees, hoverflies and wasps, *S. albida* attracted the highest abundances. Lepidoptera were the most abundant on *G. homeanum* (Figure 2, Table 2). The abundance of Hemiptera and Coleoptera varied between all flower species, but this significance did not appear in any pairwise comparisons of individual flower species. Diptera did not appear to vary significantly in abundance between flower species (p = 0.1609, Table 2).

Table 1.
PERMANOVA results for the FVI community composition between different flower species. No. permutations = 999

	d.f.	Pseudo-F	R^2	P (perm)
Flower sp.	10	22.95	0.19759	0.001
Residuals	932	0.80241	NA	NA
Total	942	NA	NA	NA

Figure 2.
The average abundance per cell of each insect group recorded at each flower species.



Discussion

The colour, morphology and abundance of flowers in each of the study plant species may explain the results found in this study. *C. cuneifolia, S. albida* and *W. communis* attracted large FVI population sizes, and all three flowers were blue. Lunau and Maier (1995) showed Hymenoptera and some hoverflies have an innate preference for the colour blue. Flower colour could thus be a useful factor to consider when restoring grasslands, in order to attract pollinators.

Table 2.
Kruskal-Wallis test results for the difference in abundance of each insect group between study plant species, and the post-hoc results showing the plant species that supported the highest abundance for each insect group.

Insect group	X^2	d.f.	*P*	Flower species with significantly highest average insect abundance
Small bee	317.8	10	<0.001	*C. cuneifolia, C. lappulacea*
Medium bee	410.14	10	<0.001	*S. albida, W. communis*
Large bee	308.15	10	<0.001	*S. albida*
Hoverfly	53.114	10	<0.001	*S. albida*
Wasp	202.15	10	<0.001	*S. albida*
Lepidoptera	151.24	10	<0.001	*G. homeanum*
Other Diptera	14.273	10	0.1609	NA
Hemiptera	31.29	10	0.0005	NA
Coleoptera	28.416	10	0.0154	NA

Relative to all other plant species, both *Calotis* species attracted high numbers of small bees. *C. cuneifolia* is blue and *C. lappulacea* is yellow, indicating that flower attributes other than flower colour, such as flower morphology or nectar rewards, may be important for attracting small bees. Around Richmond, small bees are commonly from the short-tongued family Halictidae, which feed from small, shallow flowers, such as those of *C. cuneifolia* and *C. lappulacea* (Dollin et al., 2007). Further studies, including the identification of all bees observed at *Calotis* sp. to a species level, may identify whether or not this is a specialist relationship.

G. homeanum attracted more Lepidoptera, while *S. albida* attracted the highest abundances of medium and large bees, hoverflies and wasps. *S. albida* was flowering strongly throughout the study period relative to the other plants. However, no accurate measurements of flowering intensity were made to allow definite conclusions about this. Future studies should take into account flowering intensity, so as to more accurately study the quality of plant phenotypic characteristics attractive to pollinators rather than just the quantity of resources (as in Woodcock et al., 2014).

These findings present evidence that the plants studied at the SPA can support a pollinator community that is both abundant and diverse, and are likely to support the ecosystem service of pollination. *C. cuneifolia, C. lappulacea, C. apiculatum, G. hederacea, R. lappaceus, S. albida,* and*, W. communis,* were all noted for their ability to support the overall FVI community biodiversity, or specific insect pollinator populations. They should all be recommended for inclusion in restoration seed mix. This study emphasizes the potential benefits of the careful selection of plants used in habitat restoration activities. The intentional use of the species highlighted here could maximise the abundance and diversity of insects likely to play important roles in pollination and grassland ecosystem functioning.

References

Biesmeijer, J. C., Roberts, S. P. M., Reemer, M., Ohlemueller, R., Edwards, M., Peeters, T., Schaffers, A. P., Potts, S. G., Kleukers, R., Thomas, C. D., Settele, J. and Kunin, W.E. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313, 351-354.

Dollin, A., Batley, M., Robinson, M. and Faulkner, B. (2007). *Native Bees of the Sydney Region: a Field Guide*. North Richmond, NSW: Australian Native Bee Research Centre.

Gibson-Roy, P., and Delpratt, J. (2015). "The restoration of native grasslands" in *Managing the grasslands of south-eastern Australia,* eds N. S. G. Williams, A. Marshall and J. W. Morgan (Clayton South VIC: CSIRO Publishing), 331–388.

Giraudoux, P. (2016). pgirmess: Data Analysis in Ecology. R package version 1.6.4. https://CRAN.R-project.org/package=pgirmess

Lunau, K. and Maier, E. J. (1995). Innate preferences of flower visitors. *J. Comp. Physiol. A Neuroethol. Sens. Neural. Behav. Physiol.* 177, 1–19.

Simpson, E. H. (1949). Measurement of diversity. *Nature* 163, 688-688.

Williams, N. S. G., Marshall, A. and Morgan, J. W. (2015). *Land of sweeping plains: managing and restoring the native grasslands of south-eastern Australia*. Clayton, South VIC, Australia: CSIRO Publishing.

Woodcock, B. A., Savage, J., Bullock, J. M., Nowakowski, M., Orr, R., Tallowin, J. R. B. and Pywell, R. F. (2014). Enhancing floral resources for pollinators in productive agricultural grasslands. *Biol. Cons.* 171, 44-51.