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Pollinator abundance and floral characteristics in six public parks in Glasgow, Scotland

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ABSTRACT
Global declines in both pollinators and plants are attributed to habitat loss, fragmentation, agrochemicals and climate change. Continued urbanisation is expected to further threaten species, requiring conservation of pollinator habitats in our towns and cities. The aim of this study was therefore to examine how floral species richness and floral abundance influenced pollinator abundance in parks in Glasgow, Scotland. Six sites were selected along an urban-to-peri-urban gradient (Kelvingrove Park, Botanic Gardens, Yorkhill Park, Victoria Park, Knightswood Park and Trinley Brae). Pollinator abundance and floral characteristics were recorded in quadrats along transects in June 2023. Results showed that pollinator abundance increased with floral species richness but not floral abundance. Parks had similar pollinator abundance with the exception of Victoria Park, where pollinator abundance was lower compared with other parks. This study demonstrates the importance of floral diversity to enhance pollinator communities and underpins the need for site-specific management to effectively support pollinators in public parks.

INTRODUCTION

Insect-mediated pollination networks are crucial to terrestrial ecosystem dynamics as they facilitate reproduction in 90% of angiosperms (Ollerton *et al.*, 2011; Klein *et al.*, 2007). Pollinators require access to plants for foraging resources and in return, as mobile intermediaries, pollinators play a key role in the reproductive success of these plants. However, both pollinator and plant populations are facing unprecedented challenges across the world, and these strong mutual interactions may be at enhanced risk of coextinction.

Declines in pollinator populations have been attributed to the loss, fragmentation and degradation of habitat, primarily due to urban and agricultural expansion, alongside agrochemical use and localised effects of global climate change (Goulson *et al*., 2015; Ollerton *et al*., 2014; Dicks *et al*., 2016). There are also declines in flowering plant populations across the world (Potts *et al*., 2016; Biesmeijer *et al*., 2006) which may suggest a coextinction trophic cascade (Labandeira, 2002).

Urban expansion is accelerating globally with an estimated 68% of the human population expected to live in urban areas by 2050 (The United Nations, 2018). This will likely intensify land-use change and habitat degradation pressures with notable plant-pollinator feedback (Seto *et al.*, 2012; Newbold *et al.*, 2015). However, within towns and cities, urban greenspace can present considerable conservation potential for both pollinators and plants (Baldock *et al*., 2019; Aronson *et al*., 2014; Brom *et al*., 2022). Beyond this, access to urban greenspace provides important ecosystem services to urban dwellers, acting as a natural buffer to filter air pollution while enhancing physical health outcomes and mental wellbeing (Mansor *et al.*, 2017; Li *et al.*, 2023).

A recent review by Wenzel *et al*. (2020) concluded that urban landscapes filter pollinator communities based on traits such as nesting and foraging strategy, sociality, body size and phenology, promoting cavity-nesters and generalists (polylectic) over ground-nesters and specialists (oligolectic). Furthermore, when impervious surface exceeded 50%, pollinator abundance and functional diversity decreased with urban expansion. However, following city sprawl with impervious surface below 50% (mainly peri-urban settings), pollinator abundance and functional diversity increased. These findings show good agreement with Baldock *et al.* (2015) where the diversity of hymenopterans was greater in urban areas than in farmland sites. It is suggested that species-rich assemblages of native and non-native plantings in heterogenous urban greenspaces may buffer the negative impacts of urbanisation on pollinators. These effects include exposure to pollution, the urban heat island effect and the biological effects of habitat fragmentation, including genetic drift, inbreeding depression and demographic stochasticity (Harrison & Winfree, 2015). Although pollinators are clearly sensitive to urbanisation, there are species-specific conservation opportunities in habitats within our towns and cities.

In the City of Glasgow, Scotland natural, semi-natural and the built environment offers a mosaic of key pollinator habitats (Lindsay, 2021). Grasslands and wildflower meadows are critical habitats, offering shelter and diverse nutrition (Hicks *et al.*, 2016). Leaf litter and dead wood in woodland ecosystems provide overwintering habitat and support the reproductive success of pollinators with oviposition sites. Features such as bare ground and soil, rare in urban areas due to the proportion of sealed surfaces, are important habitat to ground-nesting pollinators such as solitary wasps and mining bees, attracting cuckoo species (cleptoparasites) (Celary *et al.*, 2007; Hinners *et al.*, 2012). Cracks and crevices in urban structures provide niche habitat opportunities and overwintering sites for cavity-nesting species. Canals, rivers and other linear landscape features may provide functional landscape connectivity throughout Glasgow as ecological corridors, while private gardens and smaller greenspaces may provide stepping-stone habitat, supporting pollinator metapopulation dynamics at city-scale. Freshwater and riparian ecosystems also provide key habitats, particularly for pollinators with aquatic larvae such as *Sericomyia silentis* (common bog hoverfly).

While literature searches highlight conservation successes in Glasgow (Hayhow *et al.*, 2016; Stewart *et al.*, 2017; Weddle, 2011), data on pollinators either predate implementation of conservation strategy or are dated (Bairner, 2011, 2012, 2013). Therefore, this study aims to examine the relationship between floral species richness, floral abundance and pollinator abundance in six public parks in Glasgow and will investigate differences between sites.

MATERIALS AND METHODS

Site selection

All urban greenspace within an 8 km radius of George Square, Glasgow (NS5926665399) were identified using ArcGIS mapping software (Glasgow City Council, 2017). Categories of urban greenspace were filtered to display only public parks. Site selection followed an urban-to-peri-urban gradient from George Square towards the west of the city and to the north of the river Clyde due to practicalities in data collection. Six public parks were therefore surveyed (Fig. 1; Table 1).

Sampling pollinators

Pollinators were counted by walking along each transect and recording the abundance of insect pollinators within each quadrat. Pollinators were recorded within each quadrat for two minutes, totalling ten minutes per transect. Each individual survey was repeated after an interval of five minutes to reduce disturbance to pollinators and allow any disrupted individuals to return to forage, providing two counts per transect. Maximum pollinator abundance was determined by taking the highest pollinator abundance recorded in each quadrat from the two separate counts. All pollinators present within the quadrat were included in abundance counts. All individuals seen to leave and re-enter the quadrat were not counted twice. Pollinators were recorded into four key functional Orders of Diptera (true flies,

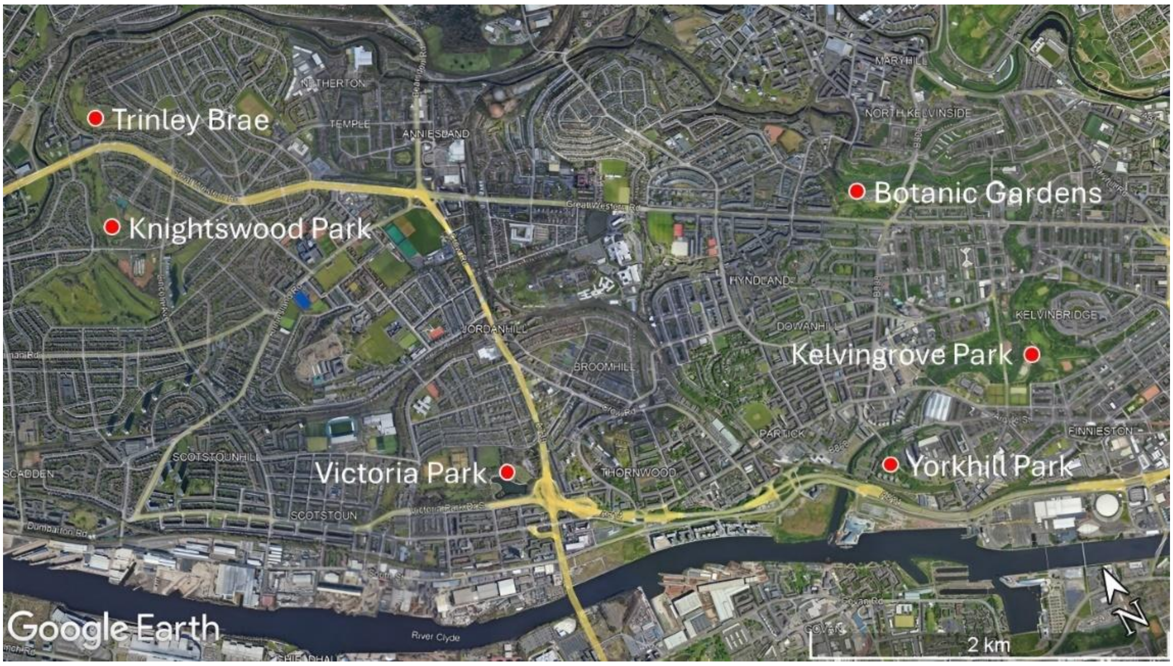

Fig. 1. Public park study sites in Glasgow, Scotland (Google Earth Pro, 2024).

Site	OS grid reference	Area (ha)	Date surveyed
Trinley Brae	NS5324970127	6	16/06/2023
Knightswood Park	NS5302769638	11	16/06/2023
Botanic Gardens	NS5673867533	20	22/06/2023
Victoria Park	NS5404267314	20	24/06/2023
Yorkhill Park	NS5612566174	5	26/06/2023
Kelvingrove Park	NS5723066426	34	26/06/2023

Table 1. Public park study sites: locations, area and date surveyed (in chronological order of site-visit).

including hoverflies and others), Hymenoptera (sawflies, wasps, ants and bees) (Fig. 2), Lepidoptera (butterflies and moths) and Coleoptera (beetles). A total of 24 transects was surveyed with 48 transect walks over the duration of the study.

Fig. 2. Bumblebee (*Bombus* sp.) foraging in Botanic Gardens, Glasgow, 22nd June 2023. (Photo: R.F. Dubbels)

Data collection

Observations took place over a two-week period in June 2023 (Table 1) and only commenced when the air temperature was within the range 12-27°C, when the windspeed was ≤25 km h^{-1}, when cloud cover was ≤50 % and there was no precipitation.

Transect and quadrat sampling

Floral species richness and pollinator abundance were counted in each site using a 10 m transect line with five 1 m x 1 m quadrats randomly placed on alternating sides of the transect. Each individual transect/quadrat survey was repeated twice and replicated a total of four times throughout each site. Quadrat placement and the start point of each transect were selected using random number generation in R version 3.4.2 (R Core Team, 2023). The overall methodology is based on FIT (flower-insect timed) counts from the UKCEH (2021) and similar primary research (Baldock *et al*., 2019; Westphal *et al*., 2008). However, the results of this study are not directly comparable with FIT counts due to differences in sampling strategies and protocols.

Data analysis

All statistical analyses and data visualisations were undertaken in R version 3.4.2. Each figure was created using the Tidyverse package (Wickham *et al*., 2019). A generalised linear mixed model (GLMM) was fitted with a Poisson distribution to predict maximum pollinator abundance with floral species richness, floral abundance and site as fixed effects. Transect was treated as a random effect in the model to account for non-independence along the same transect. The model was fitted using the glmer function in the lme4 package (Bates *et al*., 2015). Residuals were inspected using the DHARMa package (Residual diagnostics for hierarchical regression models) to ensure the fit of the model (Hartig, 2022).

Assessment of model adequacy

DHARMa plots were inspected to ensure the GLMM's reliability in predicting maximum pollinator abundance. The Quantile-Quantile plot and non-significant Kolmogorov-Smirnov (KS), dispersion, and outlier tests indicate good agreement between observed residuals and a theoretical Poisson distribution, supporting the model's assumptions. In the Residuals vs Predicted plot, no discernible pattern or systematic deviation is observed, suggesting the model's predictions align well with the observed data. The Residuals vs Predictor plot and the significant combined adjusted quantile test highlight potential deviations in certain predictor variable ranges and suggests areas where the model may be less effective.

RESULTS

Predictors of maximum pollinator abundance and model overview

The GLMM marginal R^2 suggest the fixed effects alone explain 23.3% of the variance in maximum pollinator abundance and the conditional R^2, accounting for both fixed and random effects, suggests a total explanatory power of 51.2% (Table 2).

Pollinator abundance increased with floral species richness (β = 0.13, 95% C.I. = [0.02, 0.23], P = 0.017) (Figs. 3 and 4). The effect of floral abundance on pollinator abundance was not significant (β = 0.0062, 95% C.I = [0.000903, 0.01], P = 0.087) with floral abundance counts detailed in Table 3. Maximum pollinator abundance was significantly lower in Victoria Park relative to the intercept (Botanic Gardens) (β = -0.69, 95% C.I. = [-1.20, -0.18], P = 0.008). The effect of Trinley Brae was not significant (β = -0.60, 95% C.I. = [-1.22, 0.01], P = 0.055) but should be interpreted with caution as only marginally above the 5% threshold of significance. The effect of all remaining sites on pollinator abundance was not significant relative to the intercept (Table 2)

The estimated variances within transects (σ^2 = 0.17) and between transects ($\tau_{00 \text{ Transect}}$ = 0.09) indicate notable variability in maximum pollinator abundance at this scale. The intraclass correlation value suggests 36% of the total variability in maximum pollinator abundance was due to differences between clusters/transects.

Differences in pollinator assemblages between sites

The abundance and proportion of individuals in the four pollinator orders varied notably between sites (Fig. 5). Diptera were the commonest order in all sites and were disproportionately high in Knightswood Park constituting 66% of the individuals counted. Hymenoptera were second to Diptera as the most abundant order in all sites and were most prominent in Botanic Gardens followed by Kelvingrove Park. Kelvingrove Park was the only site where hymenopteran and dipteran counts were similar, representing 39% and 36% of each total count, respectively. Lepidopterans

Predictors	Estimate	Standard error	Incidence rate ratio	95% C.I.	*P*
(Intercept)	1.62	0.21	5.03	3.32 – 7.63	<0.001
Floral species richness	0.13	0.05	1.14	1.02 - 1.26	0.017
Floral abundance	0.01	0.003	1.01	1.00 - 1.01	0.087
Site (Kelvingrove Park)	-0.06	0.25	0.94	0.57 - 1.55	0.823
Site (Knightswood Park)	-0.22	0.25	0.80	0.49 - 1.32	0.380
Site (Trinley Brae)	-0.60	0.31	0.55	0.30 - 1.01	0.055
Site (Victoria Park)	-0.69	0.26	0.50	0.30 - 0.84	0.008
Site (Yorkhill Park)	-0.09	0.25	0.92	0.56 - 1.51	0.734
Random effects					
σ^2	0.17				
$\tau_{00\ \mathrm{Transect}}$	0.09				
ICC	0.36				
N_{Transect}	24				
Observations	120				

Table 2. GLMM model output. Estimates, standard errors, incidence rate ratios (IRRs), 95% confidence intervals (CIs) and p-values for the fixed effects of floral species richness, floral abundance and site. Variance components within (σ^2) and between ($\tau_{00\ \mathrm{Transect}}$) transects and the intraclass correlation (ICC) are detailed.

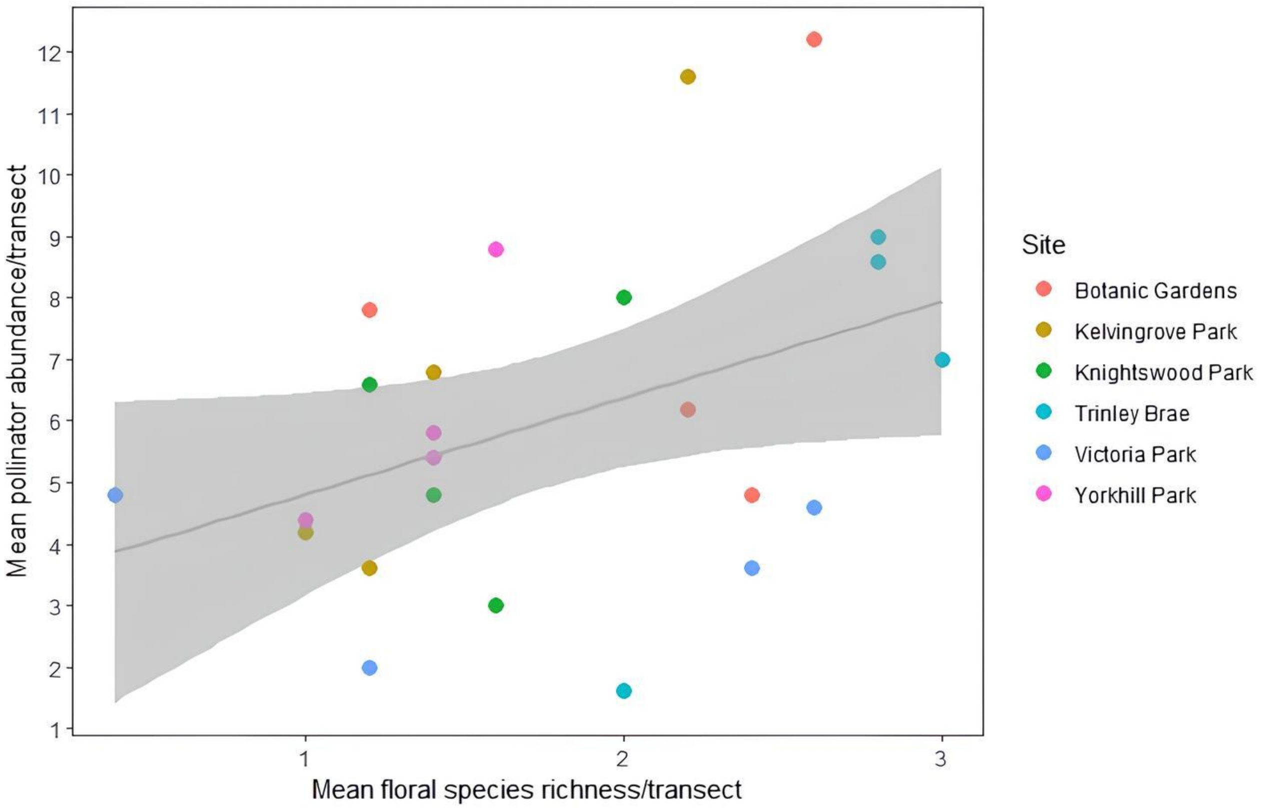

Fig. 3. Relationship between mean floral species richness and mean pollinator abundance/transect (n = 4 in all sites). Trendline fitted with simple linear regression. Shaded area represents 95% confidence interval.

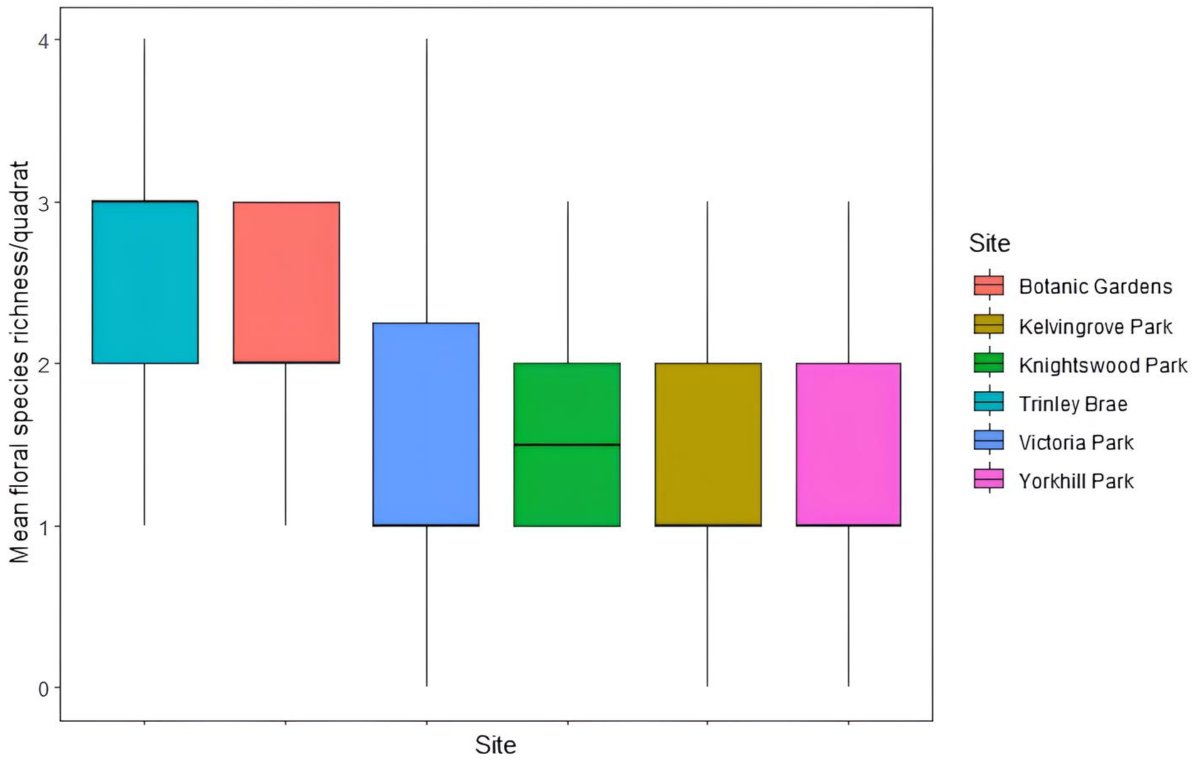

Fig. 4. Mean floral species richness/quadrat (n = 20 in all sites). Arranged in descending order of floral species richness. Quadrat size = 1 m^2. Median line situated at the top/bottom of a box represents skewed data and more extreme values. Absence of upper or lower whiskers in Botanic Gardens and Knightswood Park suggests no data beyond the 1.5 inter-quartile range.

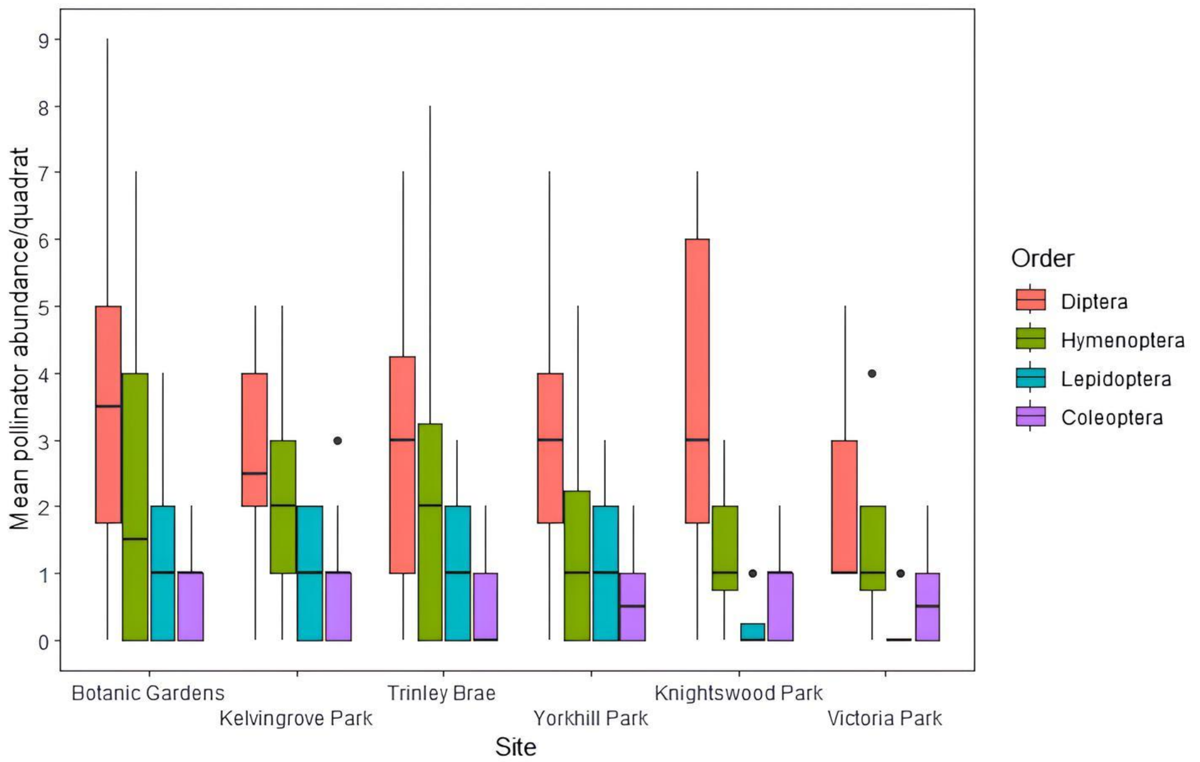

Fig. 5. Mean number of individuals of the four pollinator orders/quadrat (n = 20 in all sites). At each site arranged in descending order of maximum pollinator abundance. Quadrat size = m^2. Absence of upper or lower whiskers indicates no data points beyond the 1.5 IQR range. Black dots indicate outliers (>1.5 to <3 times the inter-quartile range) observed in coleopterans in Kelvingrove Park, lepidopterans in Knightswood Park, and hymenopterans and lepidopterans in Victoria Park.

were most abundant in Yorkhill Park where observations of Hymenoptera and Lepidoptera were proportional, representing 25% and 26% of counts, respectively. Knightswood Park and Victoria Park were the only sites where coleopterans were more abundant than lepidopterans, constituting 16% and 9% of counts, respectively. Lepidopterans were limited in Knightswood Park and Victoria Park, the sites least abundant in all pollinators, representing 3% and 4% of abundance, respectively.

DISCUSSION

Floral characteristics as predictors of maximum pollinator abundance

This study demonstrates floral species richness as a relatively strong predictor of maximum pollinator abundance, suggesting enrichment of urban greenspace with species rich floral resources may augment the abundance of pollinators (Blaauw & Issacs, 2014; Blackmore *et al*., 2014; Nichols *et al*., 2019). However, the effect of floral species richness was weaker than expected and may suggest floral enrichment alone is insufficient to enhance pollinator communities, as demonstrated in Matteson & Langellotto (2011) and Albrecht *et al*. (2020). Therefore, addressing site-specific features such as land management, anthropogenic pollution, patch fragmentation and plant-pollinator phenology is important for effective conservation of pollinators, underpinning the need for greater understanding of factors influencing pollinators across the City of Glasgow (Goulson *et al*., 2002; Reader *et al*., 2005; Holzschuh *et al*., 2007; Wesche *et al*., 2012; Walter & Bartomeus, 2020). Additionally, the unexpected non-significance of floral abundance highlights there may be a point of saturation where additional flowers yield diminishing returns, especially if pollinators are oligolectic (Gerner & Sargent, 2022). Considering the origin of floral resources, whether native or non-native, may also be important. While greater research is required to understand the merits of native and non-native plantings in pollinator conservation strategy, Salisbury *et al.* (2015) demonstrate native and near-native plantings attracted a greater abundance of pollinators compared to non-natives. However, this was subject to species-specific morphology such as tongue length as well as temporal dynamics and phenology, with greater interactions with the non-native treatment later in the season during peak bloom.

Site as a predictor of maximum pollinator abundance and variance at the transect-scale

Considering the substantial variance in pollinator abundance captured at the transect-scale (Table 2), the broader classification of site may introduce bias in our understanding of drivers of plant-pollinator interactions highlighted at this finer resolution. At this level, differences in factors such as floral characteristics, microhabitat opportunities, microclimate and small-scale differences in urban drivers of plant-pollinator interaction may play a crucial role in influencing pollinator abundance. This may suggest conservation efforts should be targeted at these finer resolutions rather than a broader approach based on site to effectively support pollinators in Glasgow. However, the effect of each site on pollinator abundance provides interesting results. Pollinator abundance was similar, although on average reduced, in Trinley Brae, Kelvingrove Park, Yorkhill Park and Knightswood Park relative to Botanic Gardens, but these differences were not significant. The effect of Trinley Brae was only marginally above the significance threshold, likely due to the impact of substantially greater floral abundance (Tables 2 and 3). Victoria Park was highlighted as the only site with significantly fewer pollinators relative to Botanic Gardens. While the analysis provides valuable insights, it is important to consider site-specific features that may impact pollinator abundance in the six public parks.

Site	Mean	Std. dev
Trinley Brae	67.1	30.0
Victoria Park	22.4	27.0
Botanic Gardens	18.4	10.1
Knightswood Park	14.0	5.50
Yorkhill Park	11.0	6.10
Kelvingrove Park	8.30	4.90

Table 3. Mean ± SD floral abundance/quadrat (n = 20 in all sites). Arranged in order of decreasing floral abundance.

Botanic Gardens and Kelvingrove Park

Botanic Gardens is a heterogenous urban greenspace rich in ecosystem complexity, with a diverse assemblage of native and non-native plantings providing a variety of foraging resources and pollinator habitats. Pollinator abundance was greatest in Botanic Gardens suggesting high quality conditions (Tables 2 and 4). Kelvingrove Park was second to Botanic Gardens (only marginally above Trinley Brae) as greatest in pollinator abundance, with relatively high floral characteristics, offering a range of woodland, grassland and riparian habitat opportunities. Botanic Gardens and Kelvingrove Park are separated by approximately 2 km and bordered by the River Kelvin, providing an important ecological corridor between these sites, as well as urban and peri-urban Glasgow (Scott, 2018). It was also noted that the Kirklee Allotment is situated along this corridor 500 m upstream from Botanic Gardens. Allotments have been shown to be pollinator conservation hotspots in urban landscapes, providing diverse nutrition and heterogenous habitat opportunities to support functionally diverse pollinators while serving as important source habitats (Baldock *et al*., 2019; Andersson *et al*., 2007; Griffiths-Lee *et al*., 2022).

Assuming adequate provision of forage and resting sites, the River Kelvin corridor may support dispersal of pollinators between the Kirklee Allotment, Botanic Gardens and possibly into Kelvingrove Park. The distance between Botanic Gardens and Kelvingrove Park likely inhibits movement of most solitary insect pollinators (Gathmann & Tschartke, 2002) but larger-bodied eusocial individuals may forage throughout the wider meta-ecosystem (Chapman *et al*., 2003). Pollinators foraging between these sites may support

Site	Mean	Std. dev
Botanic Gardens	7.75	3.56
Kelvingrove Park	6.55	3.56
Trinley Brae	6.55	3.23
Yorkhill Park	6.10	2.57
Knightswood Park	5.60	2.56
Victoria Park	3.75	1.71

Table 4. Mean ± SD maximum pollinator abundance/quadrat (n = 20 in all sites). Arranged in order of decreasing pollinator abundance.

metapopulation dynamics, mitigate habitat fragmentation pressures, enhance pollen transfer and gene flow, supporting observations between sites. Overall, pollinator abundance and floral characteristics in Botanic Gardens and Kelvingrove Park, as well as surrounding landscape features, demonstrates the ecological value of heterogenous habitat, diverse forage resources and possibly the role of allotments and functional landscape connectivity in pollinator conservation strategy (Staddon *et al*., 2010; Haddad *et al*., 2015; Townsend & Levey, 2005; Van Geert *et al*., 2010; Baldock *et al.*, 2019; Kwak *et al.*, 1998). Future research should therefore test for functional landscape connectivity in patches along the River Kelvin corridor, potentially using model organisms and genetic testing techniques to assess gene flow in pollinator populations between sites.

Trinley Brae and Knightswood Park

Trinley Brae and Knightswood Park are approximately 400 m apart, separated by rows of urban dwellings with gardens that may serve as ecological stepping stones and by Glasgow's Great Western Road. While some larger-bodied pollinators may disperse between sites, roads present significant barriers for dispersal, particularly for smaller-bodied taxa (Chapman *et al.*, 2003; Fitsch & Vaidya, 2021).

In Knightswood Park, a considerable proportion of pollinators were dipterans, constituting the most homogenous community across the six sites, with implications for ecosystem production and function (Fig. 5) (Oliver *et al*., 2015). Along with lepidopterans, dipterans may be less efficient pollinators than hymenopterans (Herrera, 1987) showing good agreement with floral characteristics recorded in the site (Fig. 4; Table 3). Knightswood Park consists primarily of intensively managed amenity grassland, with intense mowing regimes that have been shown to negatively correlate with the abundance and diversity of hymenopterans, which is consistent with our observations (Lerman *et al.*, 2018). Aquatic and riparian habitats in Knightswood Park Pond and Garscadden Burn, located to the south and along the west of the site respectively, may support pollinators with aquatic larvae by providing breeding habitats and oviposition sites. This may explain the high abundance of dipterans in Knightswood Park. However, Diptera were the most abundant order across all sites, including Trinley Brae, where no aquatic or riparian habitats are present.

The size of habitat has strong biodiversity feedbacks, but smaller greenspaces can still support viable pollinator populations, contingent upon availability of quality habitat and resources (Wilson & MacArthur, 1967; Aronson *et al*., 2014; Scheper *et al*., 2015; Meyer *et al*., 2009; Zalucki *et al*., 2002). Despite Trinley Brae's comparatively small area (Table 1) it supports disproportionately high pollinator abundance and the greatest floral characteristics of all sites. During the site visit, it was noted that Trinley Brae shares its eastern border with the Trinley Brae allotment. Pollinators foraging between these sites may support metapopulation dynamics, reducing habitat fragmentation and edge-effect pressures, common in smaller sites. The allotment may also serve as source habitat for some pollinators. It was observed incidentally that pollinator abundance and floral characteristics appeared more dense towards the east of the site and less dense towards the west. However, this study focused exclusively on public parks, without accounting for the effect of different categories of urban greenspaces (allotments, private gardens, brownfield) on pollinator abundance. Future work should therefore establish how different categories of greenspace influence the abundance and functional diversity of pollinators in Glasgow, to better support plant-pollinator community robustness at city-scale.

Victoria Park

Victoria Park was the only site with significantly fewer pollinators relative to Botanic Gardens, despite both sites being similar in area and floral species richness. In contrast to Botanic Gardens, Victoria Park is markedly fragmented within the urban matrix. Due to the lack of landscape connectivity, all resource requirements must be satisfied from within the single site, and habitat patches must be sufficient in area and resource diversity to support pollinators (Lepczyk *et al*., 2017). A substantial proportion of Victoria Park consists of intensively managed amenity grassland with implications for the abundance and diversity of hymenopterans (Lerman *et al*., 2018). This is generally consistent with our observations in the site, excluding the northernmost transect in Victoria Park, where a substantial number of hymenopterans were recorded adjacent to *Philadelphus pubescens* (hoary mock orange) (Fig. 5). There are Victorian-style floral displays throughout the site consisting of one or two ornamental flowering plants. While people can enjoy these floral displays, they may provide pollinators monotonous diet opportunities with implications for fitness and productivity (Dance *et al*., 2017).

There is a city-managed wildflower meadow in the southern border of the site under a shaded canopy and adjacent to a dual carriageway. Solar irradiance is important in plant-pollinator interactions which may influence the utility and attractiveness of the meadow (Kilkenny & Galloway, 2008). Furthermore, research suggests pollutants in vehicle exhaust, such as elevated ozone and nitrous oxides, can be detrimental to plant-pollinator interactions (Ceulemans *et al*., 2017; Ryalls *et al*., 2022). Enrichment of the meadow with more shade-tolerant plants and effective management may mitigate these impacts to enhance utility of the meadow.

In contrast to findings in Baldock *et al*. (2015), diverse and abundant floral resources in Victoria Park did not appear to buffer the negative effects of urbanisation on pollinators. Interconnected stressors and pressures in this park, such as the biological effects of habitat fragmentation, exposure to pollutants and possibly land management practices, may contribute to the observed lack of pollinators. Future work is therefore required to better understand and quantify these pressures in future analyses, and to a underpin targeted conservation strategy aimed at remedying and supporting pollinator populations in Victoria Park.

Yorkhill Park

Yorkhill Park is situated along the River Kelvin corridor, approximately 1 km downstream from Kelvingrove Park, close to its confluence with the River Clyde. Pollinators, particularly lepidopterans, were surprisingly abundant in Yorkhill Park despite relatively poor floral species richness and floral abundance. Community-led management of the site by Yorkhill Green Spaces (YGS) may support the abundance with regions of wildflower plantings (largely unaccounted for due to randomised sampling) with a variety of pollinator habitats in wooded areas and grassland. It has also been suggested that the urban heat island effect influences pollinators (Merckx *et al*., 2021) but there is no evidence of this in Glasgow (Plant, 2023). Greater research is required to determine what factors are driving the abundance of pollinators, especially lepidopterans, in this site. It should be noted that observed differences in pollinator abundance and assemblages may be due partly to variations in meteorology, timing of site visits, experimental design and the spatial dynamics of pollinators foraging throughout heterogenous urban greenspaces (Karbassioon & Stanley, 2023). Furthermore, capturing pollinators may produce more reliable abundance counts, as, despite protocols, it is possible some pollinators were counted more than once or were missed entirely.

Floral taxa and existing pollinator conservation strategy

Leucanthemum vulgare (oxeye daisy) provides important summer forage and was observed in all sites except Knightswood Park. *Trifolium repens* (white clover), *Ranunculus* spp. (buttercups) and *Bellis perennis* (common daisy) were recorded in all sites, predominately in amenity grassland, and were the only floral resources observed in Knightswood Park. Hymenopterans and lepidopterans were notably attracted to *Achillea ptarmica* (sneezewort) and oxeye daisy in Trinley Brae, and hymenopterans to hoary mock orange in the northern-most transect in Victoria Park. An existing pollinator conservation strategy includes city- or community-led management of wildflower meadows in all sites except Knightswood Park. City-managed meadows consist of native plantings including oxeye daisy, *Lotus corniculatus* (common bird's foot trefoil), *Silene dioica* (red campion) and *Rhinanthus minor* (yellow rattle), the last being a hemi-parasitic angiosperm which feeds on fine roots of grasses, allowing wildflowers to compete for limiting nutrients (Seel & Press, 1996). In Trinley Brae, regions of bare ground are maintained to offer burrowing opportunities to ground-nesting pollinators such as solitary wasps and mining bees. Other invertebrates including *Omocestus viridulus* (common green grasshopper) were observed in the thicket of Trinley Brae and Victoria Park.

Conclusion

This study examined pollinator abundance in public parks throughout Glasgow. Floral species richness was a relatively strong predictor of maximum pollinator abundance, while floral abundance appeared to be less important, and differences in site-specific factors were highlighted. Enhancing urban greenspaces with diverse floral resources may increase the abundance of insect pollinators. High quality resources, proximity to allotments and potential landscape connectivity facilitated by ecological corridors and stepping stone habitat may support the observed abundance of pollinators in Botanic Gardens, Kelvingrove Park and Trinley Brae. Following the difference in pollinator abundance between Botanic Gardens and Victoria Park, further research is required to understand and quantify the site-specific pressures facing pollinators in Victoria Park. This work may focus on the biological effects of habitat fragmentation, exposure to anthropogenic pollutants and other important urban-drivers of plant-pollinator interaction. Achieving a better understanding of site-specific and city-scale factors affecting pollinators in Glasgow is critical to complement floral enrichment in an integrated approach to conservation, and to help sustain pollination services and our urban greenspaces into the future.

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