Effects of Patch Size and Land Cover on Body Size of Bee Communities in Denver Parks

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Abstract:

With many bee species at risk of extinction and others suffering population declines, green spaces can be a valuable tool to conserve bees in developed areas. Bees are highly diverse, so species with certain traits might thrive in some parks while others will be more successful in parks with different characteristics. Therefore, research is necessary to examine how various park traits affect the type of bees that can live in them. This study looked at how body size of bee communities in urban parks was affected by park size, proportion of green space, and proportion of natural vegetation. We collected 3193 bees from 25 parks in Denver in summer 2023 and measured intertegular distance in fall 2024 to represent body size. We hypothesized that community weighted mean body size would decrease as park size, green space, and natural vegetation cover increased as larger bees are able to fly farther to obtain food, allowing them to survive in lower quality habitat. Instead, we found no relationship between body size and green space (p=0.64) and only a weak correlation between natural vegetation cover and body size (p=0.27). We also found no relationship between park size and body size when analyzing the full data set (p=0.32). However, when the two largest parks were removed from the analysis, community weighted mean body size increased logarithmically as park size increased (p=0.06). These results suggest that vegetation and land cover have little impact on the size of bees present in urban parks, but park size does have an impact, with smaller bees being more prevalent in smaller parks.

Introduction:

As pollinators, bees play a vital role in both their native ecosystems and agriculture (Khalifa et al., 2021; Zattara & Aizen, 2021). However, bee populations are in decline all over the world, including in Colorado, where about 20% of native bee species are endangered (Armstead et al., 2024; Zattara & Aizen, 2021). In addition to conserving bees in their natural habitats, it is increasingly important to conserve bees in urban areas due to increased urbanization (Birdshire et al., 2020). One way to achieve this is through parks and other green spaces, which provide patches of habitat for bees to survive amid development (Bennett & Lovell, 2019).

However, bees vary significantly in their ecology and traits such as size, so a specific park might only be suitable for certain species. Parks also have widely varied traits, including size, vegetation cover, and amount of impervious surfaces. Prior research has been done on how these characteristics affect bee communities in general, finding that cities with more fragmented green space have larger-bodied bee communities (Ferrari & Polidori, 2022; Fitzgerald et al., 2022). However, research looking specifically at these urban green spaces is limited. Therefore, research is needed into how different characteristics of urban parks affect the types of bees they can support.

This study looked at how community weighted mean intertegular distance (a measure of body size) varies with differences in park size and the proportion of each park covered by green space (any vegetation) and natural vegetation (excluding turf grass). This is essential to conservation, so that managers know what features of green spaces will be most effective for the species they are looking to protect based on size. Past studies have shown that foraging distance increases with body size as larger bees are able to fly farther (Greenleaf et al., 2007; Jauker et al., 2013; Kendall et al., 2022). Therefore, we predict that parks with lower quality habitat will support more large bees, so community weighted mean body size is expected to decrease as park size, green space, and natural vegetation cover increase.

Methods:

Study Area: Bees were collected from 25 green spaces in the city of Denver, hereafter referred to as parks. These included city parks, open spaces, and one golf course. Parks ranged in size from 4 to 314 acres, with a median area of 29 acres. Land cover varied considerably among the study parks, with some being dominated by turf grass, while others have primarily native vegetation, consisting of short grass prairie and shrubland. The study area has an elevation of around 1600 meters and a semi-arid climate, receiving about 40 cm of precipitation a year. Denver is also a major city with 716,000 and 2.9 million people in the metropolitan area (Birdshire et al., 2020).

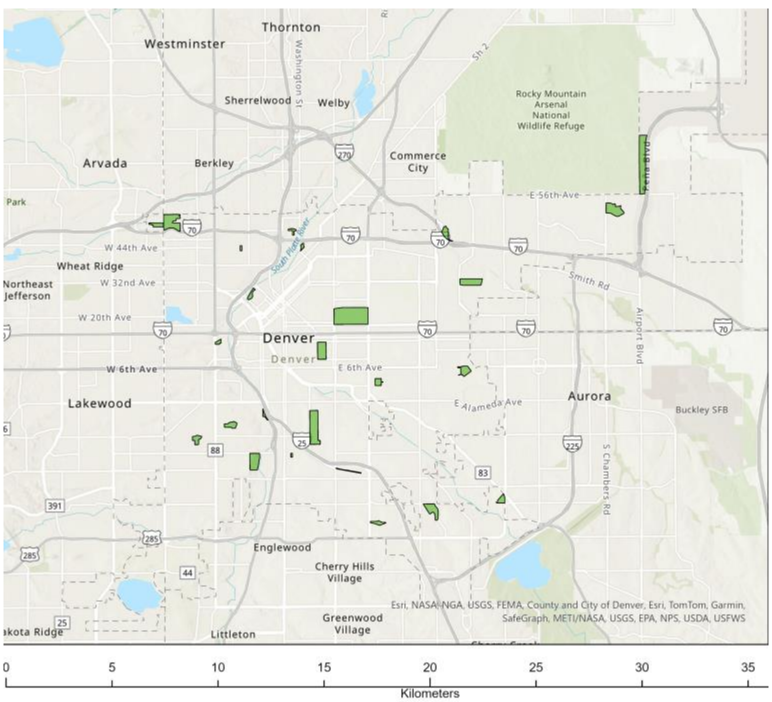

Figure 1: Map of the 25 parks in the study area.

Specimen Collection: Bees were collected in June-August 2023 by two research assistants. Each park contained two 100 meter transects in areas with dense vegetation, and in areas where there wasn't 100 meters straight of vegetation, lawn grass. Researchers walked each transect for 15 minutes, catching any bee along the transect with a hand net. Some queens were identified and recorded, but not collected. Bees were then identified to the species level and mounted in the lab. Those that could only be identified to the genus were given a number for the species. The total sample size is 3193 bees, with 3177 collected specimens and 16 queens. 137 species were represented.

Measurements: I measured intertegular distance (ITD) of the collected bees in September-October 2024 to represent body size. I took 3 measurements using a calipher for each specimen and averaged these measurements to get the ITD for each individual. If there were 10 or fewer individuals of a species, I measured all individuals. For species with a queen that wasn't collected, I measured a queen in the collection from another project and used this as the ITD for our specimen. For species with more than 10 specimens, I only measured the first 10. For these species, I averaged the ITD of the measured specimens and used this as the ITD for non-measured specimens. The ITD of 2434 individuals was acquired this way, with 759 being directly measured.


Figure 2: Intertegular distance shown on a bee

Data Analysis: I averaged the ITD of every individual found at each park to get a community weighted mean ITD. Number of bees collected at each park ranged from 61 to 281. Acreage of each park was acquired from the "Parks" layer by EsriTrainingSvc from the ArcGIS Online portal. For green space and natural vegetation cover, I used the Land Cover Raster Data 2020 layer from the Denver Regional Council of Governments. Using the zonal histogram tool in ArcGIS Pro, I was able to calculate proportions of green space and natural vegetation cover using the land cover data. For percent green space, the land cover categories "structures", "impervious surfaces", "water" and "barren rock" were excluded. Therefore, green space was composed of "Grassland/Prairie", "Tree Canopy", "Irrigated Lands/Turf", "Cropland" and "Shrubland/Scrubland". To get natural vegetation, I counted the same categories as green space but excluded "Irrigated Lands/Turf" and "Cropland". After acquiring all the data for community weighted men body size, park size, percent green space, and percent natural vegetation, I used R Studio to analyze the data. I ran linear, quadratic, cubic, and logarithmic regressions for each relationship.

Results:

The regression type (linear, quadratic, cubic, or logarithmic) with the best fit is the one reported for each analysis.

The null model that community weighted mean body size was constant was a better fit than any of the factors I examined (table 1).

Model selection based on AICc:

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Null	2	32.77	0.00	0.47	0.47	-14.11
NaturalVegetation	3	34.03	1.26	0.25	0.73	-13.45
Size	3	34.28	1.51	0.22	0.95	-13.57
GreenSpace	4	37.21	4.44	0.05	1.00	-13.61

Table 1: AIC table for the effect of the various factors (park size, proportion of green space, proportion of natural vegetation cover) on community weighted mean ITD.

Park Size:

There was no correlation between park size and community mean ITD (figure 3). The null model was a better fit, with an AICc weight of 0.68.

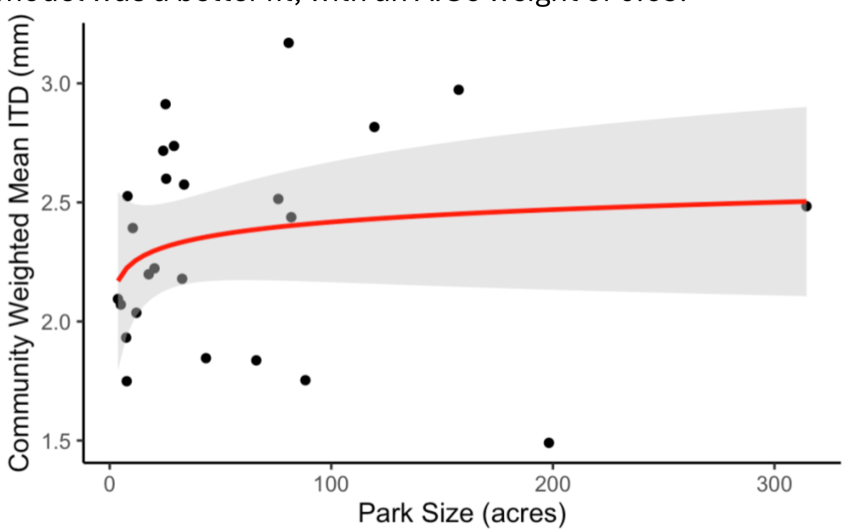

Figure 3: Plot of park size vs. community weighted mean ITD. P = 0.3223, R-squared = 0.0001.

When I ran the analysis again with the two parks that were significantly larger than the rest excluded, there was a relatively strong positive correlation (figure 4).

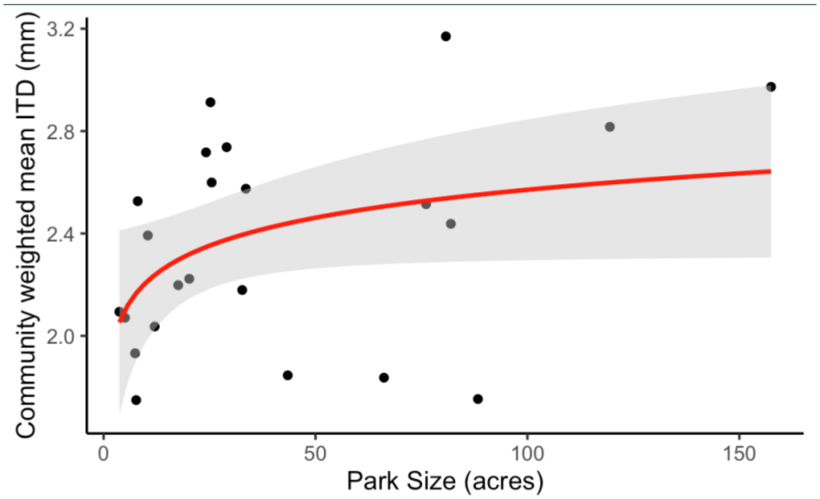

Figure 4: Plot of community weighted mean ITD vs. park size with the 2 largest parks removed. P = 0.0571, R-squared = 0.1219.

The model that there is a logarithmic relationship between park size and community weighted mean body size had the highest weight this time (table 2).

Model selection based on AICc:

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
logSize	3	26.92	0.00	0.37	0.37	-9.83
Size	3	27.13	0.21	0.33	0.70	-9.94
Null	2	28.32	1.40	0.18	0.89	-11.86
Size^2	4	29.94	3.01	0.08	0.97	-9.86
Size^3	5	31.82	4.90	0.03	1.00	-9.14

Table 2: AIC table for linear, logarithmic, quadratic, and cubic relationships between body size and park size with the two largest parks removed.

Green Space:
There was also no correlation between proportion of green space and community mean body size (figure 5).

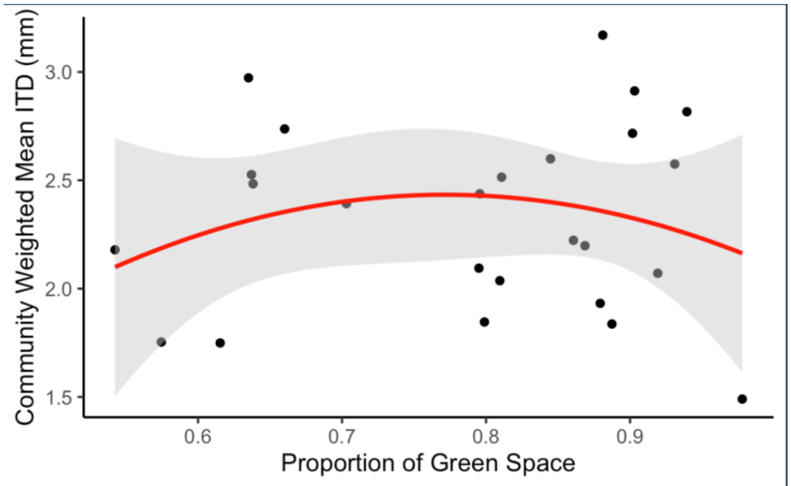

Figure 5: Plot of community weighted mean ITD vs. proportion of green space. P = 0.6401, R-squared = -0.0476.

The null model that the proportion of green space had no effect on mean body size was the best fit with an AIC weight of 0.9.

Natural vegetation
There was a slight negative relationship between community weighted mean body size and proportion of natural vegetation, but this was not significant (figure 6).

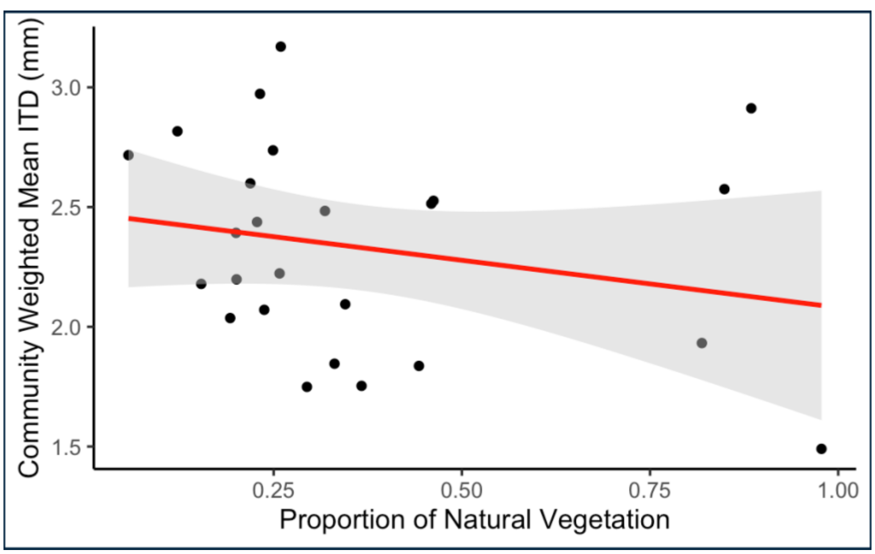

Figure 6: Plot of community weighted mean ITD (mm) vs. proportion of natural vegetation cover with a best fit line. P = 0.2731 and R-squared = 0.0108.

The null model that there is no relationship between body size and proportion of natural vegetation was still the most parsimonious model with an AIC weight of 0.65 despite the slight correlation. As there were four parks with significantly higher proportions of natural vegetation (>0.8 when the others were <0.5), I ran the analysis with these parks removed to see if the relationship was only at low proportions. This produced a slightly lower p-value of 0.1493, but the null model was still the most parsimonious with an AIC weight of 0.55.

Discussion:

My hypotheses that community weighted mean body size would be larger in smaller parks and parks with less green space and natural cover were not supported. I found no correlation between green space and body size and only a very weak correlation between natural vegetation and body size. For park size, I only found a correlation when removing the two largest parks, which were 5-10 times larger than most of the other parks. Larger bodied bees can fly further so I hypothesized that they would be able to survive in lower quality habitat as they can disperse easier to find food (Jauker et al., 2013). However, this was mostly shown not to be the case for the two land cover variables. P-values were just 0.64 for green space (figure 5) and 0.27 (figure 6) for natural vegetation, showing no meaningful relationship.

The p-value for park size was 0.32, also suggesting no correlation (figure 3). However, this decreased to 0.057 when the largest parks were removed from the analysis (figure 4). These two parks had areas of 198 and 314 acres, while the next highest was 157 acres. So, while these two parks aren't outliers in terms of size, this does suggest a positive logarithmic relationship between park size and body for smaller parks. The slope is sharpest for parks under 50 acres, then levels off. This suggests that bigger parks can support bees of all sizes, while at small sizes, small bee species are more successful. This contradicts both my hypothesis and several prior studies (Ferrari & Polidori, 2022; Jauker et al., 2013). It is likely that the small parks in our study are just big enough to have enough resources for smaller bees, which need less due to their size, so they don't need to disperse (Ferrari & Polidori, 2022; Fitzgerald et al., 2022). Then, as parks get bigger, they can support larger bees until eventually they have enough resources to support bees of any size, so the slope levels off. A possible explanation for why smaller parks had smaller bees is that the smaller parks didn't have enough resources for larger bees and were too isolated from other green spaces for large bees to obtain food elsewhere. If this is the case, then the relationship might align more with the literature if the parks were relatively close together. Future research should examine how isolated from nearby green spaces these parks are to determine if the theory that the small parks are too far away from other parks for even large bees to disperse to is supported.

From the lack of correlation between green space and body size, I can infer that a majority of the patch (all parks had >50% green space) having vegetation is enough to support a wide range of bee species. This contradicts previous research that found a strong positive correlation between impervious surfaces (essentially the inverse of green space) and large bodied bees (Bennett & Lovell, 2019). A possible explanation is that the prior study had sites that were primarily covered by impervious surfaces, so the relationship could have come from small bees not surviving in sites with little green space. However, in our study, every park had >50% green space, so a relationship at low green space cover would not have been detected (Bennett & Lovell, 2019). Perhaps the most likely reason for the lack of correlation here is that "green space" is very broad, with the percent of turf grass ranging from 0-84% and other parks having up to 80% grassland. With so much variation in the type of green space, it is no surprise that there was no relationship with community mean body size. Therefore, not much weight should be put on these green space results. Future studies should examine just the proportion of turf grass, rather than the umbrella category of green space which includes both native and planted vegetation.

There was a slight negative trend in body size as percent natural vegetation increased ($p=0.27$), but this wasn't enough to be significant. Natural vegetation cover varied significantly, from 6% to 98%. This largely depends on management, with open spaces managed for conservation having significantly more than city parks, which are often dominated by turf grass. The slight negative relationship suggests that large bees, which can disperse farther to find food, are somewhat better able to inhabit parks with few national resources (Fitzgerald et al., 2022). When there is lots of native vegetation, bees don't need to disperse, so smaller bees become more prevalent (Jauker at al., 2013). However, the relationship is weak, showing that natural vegetation doesn't have much of an effect on bee communities in terms of what sized bees are present. The negative correlation supports past research, but these studies had stronger relationships (Bennett & Lovell, 2019; Jauker et al., 2013).

One limitation of this study is that due to time constraints, only 759 of 3193 bees were measured, with the others having their CWM estimated using the average of the measured bees of their species. This means that the CWM estimates could be off as 10 bees isn't necessarily large enough to capture intraspecies variation. Intraspecific body is also found to vary with location, often based on characteristics like patch size and floral resources, which our parks varied substantially in (Brasil et al., 2013; Fitzgerald et al., 2022). Therefore, if the 10 measured bees of a species happened to be from a certain site or two, this could bias the CWM average. Additionally, this study would need to be replicated in other cities, to be able to draw conclusions about bee communities in general and not just in Denver. When there are millions of bees, 3193 isn't a particularly large sample size, so doing this study at a larger scale would be necessary to support these results. This study also only considered the area within the park and did not consider the landscape surrounding the park, which could have had an impact on bee communities in the park. For example, parks in a suburban or rural area with lawns or other vegetation nearby should be better able to support small bees than those surrounded by development (Birdshire et al., 2020).

Despite these limitations, we can still conclude that overall green space doesn't affect community mean bee body size, natural vegetation has a slight negative correlation with body size, and that there is a positive relationship between patch size and body size for smaller green spaces. These results suggest that in order for urban green spaces to be successful at protecting larger bodied bee species, they need to be greater than about 20-30 acres, with smaller parks having lower community weighted mean body size, showing they are more suitable for small bees. However, further research should still be conducted into isolation from other parks and account for land use surrounding the parks. For smaller bees, it would be beneficial to have increased native vegetation as opposed to turf grass. Overall green space was found not to relate to body size, so planting native vegetation is more important to bee body conservation than reducing impervious surfaces in parks. However, further research is still needed at a larger scale and with more specimens directly measured to support these results.

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