*Pollinator occupancy rates in urban landscapes are associated with natural habitat area and income.*

Abstract – I often find writing a ~150 word abstract a super useful exercise at this stage!

As the intensity and extend of urbanization increases globally, it is critical to determine the drivers of urban biodiversity patterns and the spatial and temporal scales at which these drivers operate

1. **Introduction**

**First intro paragraph:** The intensity and extent of urban land use is increasing globally (Seto et al., 2012). By the year 2050, over 70% of the world’s population is projected to live in urban areas (United Nations, 2018). At the same time, urbanization is associated with changes to the spatiotemporal composition and configuration of critical habitat and other resources, with the potential for negative impacts on biodiversity (McKinney, 2006; Grimm et al., 2008; spatial; Leong et al., 2016; Eichenberg et al. 2021). In order to reduce the loss of biodiversity and associated ecosystem services in an urbanizing world, we need to better understand the drivers of urban biodiversity patterns and the spatial and temporal scales at which these drivers operate. Identifying these drivers as well as their spatiotemporal scale dependence is especially pressing for pollinators, a functional group that provides valuable ecosystem services across a variety of landscapes, including in urban environments (pollination of native plants e.g., Cheptou et al, 2006; and urban agriculture eg. Potter et al. 2015, Lin et al., 2015; Jha et al., 2023) but that is also widely facing global declines, in part due to global land use change itself (refs).

**Last Intro paragraph:** With a focus on bumble bees and hoverflies as indicators of urban pollinator biodiversity, we use NHC’s to test two hypotheses that link among city differences (in?) to landscape-scale urban biodiversity conservation. First, we test the hypothesis that undeveloped natural habitats embedded in the urban landscape, such as…, are favourable for pollinator population growth and, simultaneously, that cities that harbour a greater overall area of favourable natural habitat mediates species conservation by compensating for local subpopulation extinctions. Second, ~~while accounting for natural habitat area in the urban landscape,~~ we use relative income as a proxy measure to test the hypothesis that high plant diversity is favourable for pollinator population growth and, simultaneously, that higher average plant diversity across a landscape mediates species conservation by similarly promoting establishment of robust subpopulations that may compensate for local extinctions. If these sets of hypotheses are true, we predict that occupancy of urban landscapes within the range of each pollinator species is positively associated with total natural habitat area and average income. Further, by testing for a negative correlation between species-specific effects of natural habitat area on occupancy and species-specific range wide occupancy rates, we assess the secondary hypothesis that occupancy rates of rare (versus common) species are more dependent on the total natural habitat area in the urban landscape.

First, we test the hypothesis that undeveloped natural habitats embedded in the urban landscape, such as…, are favourable for (local?) pollinator occupancy and, simultaneously, that greater overall area of natural habitat in the urban landscape compensates for local extinctions thereby driving higher landscape-scale pollinator occupancy rates.

Second, using income as a proxy measure for plant diversity and management resources, we test the hypothesis that higher income is favourable for (local?) pollinator occupancy and, simultaneously, that higher average income across an urban landscape compensates for local extinctions thereby driving higher landscape-scale pollinator occupancy rates.

landscape-scale pollinator occupancy is higher in urban landscapes that harbour a greater overall area of natural habitat because this may enable additional populations in the landscape to compensate for local subpopulation extinctions.

**First Discussion paragraph:** While previous studies have identified drivers of locally observed urban pollinator biodiversity, to our knowledge this is the first study to use an across city comparison to test whether two proxies for pollinator habitat (natural area and neighbourhood income) predict biodiversity patterns across broad spatial and temporal scales. We found that individual bumble bee species show wide variation in their responses to natural habitat area in the urban landscape, however, our results indicate that the occupancy rate of the average bumble bee species does not have a strong association with total natural habitat area. On the other hand, our results identify a weak positive association between bumble bee occupancy rates and relative income of the urban landscape (a proxy measure for plant diversity and vegetation management resources), highlighting that investment in management of the vegetation in the matrix of the anthropogenic landscape itself, separate from inclusion of large areas of undeveloped habitat, is a key component of urban pollinator conservation. Interestingly, we found the opposite pattern for hoverflies, with hoverflies exhibiting a positive association between total natural habitat area and landscape-scale occupancy. This result emphasizes that natural habitat remnants such as urban greenbelts and nature reserves remain essential for some pollinator taxa to persist. Together, our results indicate that drivers of local pollinator abundance and diversity also operate at larger spatial and temporal scales, mediating landscape-scale urban pollinator occupancy – although with different drivers and the strength of the effect varying among species and taxonomic groups. Here we discuss assumptions and limitations of our data and analysis as well as the implications of these results for urban biodiversity conservation applications and, moreover, for our understanding of the spatiotemporal scale dependence of biodiversity patterns.

**Last Discussion paragraph:** Much of urban ecology and conservation science, and ecology generally, is focused on quantifying biodiversity metrics at a local scale, assuming that local populations and communities are spatially closed and isolated (Leibold et al., 2004; Chase et al., 2020). With this study we examined relationships between the environment and species occupancy at multiple broader spatial scales to test the hypothesis that city-wide landscape quality mediates city-wide pollinator biodiversity. For hoverflies, urban landscapes with larger amounts of natural habitat area sustain groups of interconnected populations, while for bumble bees, affluent urban landscapes with presumably more resources to invest in vegetation cover and management – including in the developed urban matrix itself – sustain groups of interconnected populations. Thus, the fate of a species in the landscape is mediated not just by the local demography of a subpopulation, but also by the broader environment collectively experienced by all subpopulations (as is suggested by metapopulation and metacommunity perspectives) (Leibold et al., 2004; Chase et al., 2020). The properties of the broader overall landscape may influence landscape-scale species persistence by moderating the degree to which subpopulations can compensate for local extinctions due to environmental or demographic stochasticity (Leibold et al., 2004; Chase et al., 2020). The conclusions from this cross-landscape analysis call for increased consideration of the interplay between local population and community dynamics with landscape to regional dynamics. In application, this demands that local urban habitat restoration and enhancements coordinate with city-wide policy and planning to ensure long-term success of species conservation.