Environmental Research 158 (2017) 255–268

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

A spatial framework for targeting urban planning for pollinators and people with local stakeholders: A route to healthy, blossoming communities?

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ARTICLE INFO

Keywords:
Nature-based solutions
Stakeholder engagement
Urban planning
Multiscale habitat suitability model
Health and well-being

ABSTRACT

Pollinators such as bees and hoverflies are essential components of an urban ecosystem, supporting and contributing to the biodiversity, functioning, resilience and visual amenity of green infrastructure. Their urban habitats also deliver health and well-being benefits to society, by providing important opportunities for accessing nature nearby to the homes of a growing majority of people living in towns and cities. However, many pollinator species are in decline, and the loss, degradation and fragmentation of natural habitats are some of the key drivers of this change. Urban planners and other practitioners need evidence to carefully prioritise where they focus their resources to provide and maintain a high quality, multifunctional green infrastructure network that supports pollinators and people. We provide a modelling framework to inform green infrastructure planning as a nature based solution with social and ecological benefits. We show how habitat suitability models (HSM) incorporating remote sensed vegetation data can provide important information on the influence of urban landcover composition and spatial configuration on species distributions across cities. Using Edinburgh, Scotland, as a case study city, we demonstrate this approach for bumble bees and hoverflies, providing high resolution predictive maps that identify pollinator habitat hotspots and pinch points across the city. By combining this spatial HSM output with health deprivation data, we highlight 'win-win' opportunity areas in most need of improved green infrastructure to support pollinator habitat quality and connectivity, as well as societal health and well-being. In addition, in collaboration with municipal planners, local stakeholders, and partners from a local greenspace learning alliance, we identified opportunities for citizen engagement activities to encourage interest in wildlife gardening as part of a 'pollinator pledge'. We conclude that this quantitative, spatially explicit and transferable approach provides a useful decision-making tool for targeting nature-based solutions to improve biodiversity and increase environmental stewardship, with the aim of providing a more attractive city to live, work and invest in.

1. Introduction

Bees and hoverflies are vital components of urban ecosystems; they support the functioning and resilience of typically ecologically fragile and fragmented areas of urban greenspace by contributing to pollination, biodiversity and pest control (Fontaine et al., 2006; Hall et al., 2016). Their interaction with flowers results in a wide range of direct and indirect benefits to people in cities, most obviously by supporting urban agriculture via pollination, but pollinator insects and their habitats also provide cultural and health-related benefits to society by presenting opportunities to interact with nature (Bates et al., 2011; Maller et al., 2006). Grasslands that are infrequently mowed and developed into urban meadows with a diverse wildflower mix provide important pollinator habitats; they also tend to be regarded as more visually attractive than traditional amenity grassland (Blaauw and Isaacs, 2014; Garbuzov et al., 2015; Hicks et al., 2016; Hülsmann et al., 2015; Southon et al., 2017). Pollinators are also good indicators of urban biodiversity (Blair, 1999; Paoletti, 2012) and people have been found to state a preference for, or self-report more psychological benefits from, areas with higher levels of biodiversity (Fuller et al., 2007;

Abbreviations: CIR, Colour infra-red; DTM, Digital Terrain Model; DSM, Digital Surface Model; ELL, Edinburgh Living Landscape; HSI, Habitat Suitability Index; HSM, Habitat Suitability Model; LERC, Local Environmental Record Centre; MTSS, Maximum Training Sensitivity and Specificity; NDVI, Normalized Difference Vegetation Index; NGO, Non-Governmental Organisation; OBIA, Object Based Image Analysis; SIMD, Scottish Index of Multiple Deprivation; TG, Target Group

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http://dx.doi.org/10.1016/j.envres.2017.06.023
Received 2 December 2016; Received in revised form 5 May 2017; Accepted 21 June 2017

Lindemann-Matthies et al., 2010; Shwartz et al., 2014; Carrus et al., 2015; although see Qiu et al., 2013). Pollinator-friendly, species rich urban areas are therefore likely to provide a 'biodiversity feel good factor' (Dallimer et al., 2012), contributing to the health and well-being of people living and visiting towns and cities (although further evidence and careful analysis is required to 'unpack the people-biodiversity paradox' (Pett et al., 2016)).

Actions to support pollinators and their habitats are increasingly important as evidence from field studies (largely in Europe and North America) has highlighted a decline in pollinator species diversity and the contraction in many species' range (Potts et al., 2010). These are likely to be caused by multiple, inter-related factors, including the loss, degradation and fragmentation of habitats; use of agrochemicals; spread of pathogens; a changing climate (Blaauw and Isaacs, 2014; Garibaldi et al., 2011; Gill et al., 2016; Potts et al., 2010; Ricketts et al., 2008; Vanbergen, 2013). One study reported a 76% reduction in the frequency of bumble bee forage plant presence across the UK between 1978 and 1998, exhibiting a greater magnitude of change than other plant types (Carvell et al., 2006). At landscape scales, the reduction and fragmentation of semi-natural habitats as a result of urbanisation threatens pollinators by decreasing the amount and quality of foraging and nesting resources (Bates et al., 2011; Harrison and Winfree, 2015; Hernandez et al., 2009). However species-, taxon- and context-specific effects of urbanisation have been found and some studies have reported higher bee abundance or activity in urban study sites compared to farmland sites (Baldock et al., 2015a; Kaluza et al., 2016), and the landscape heterogeneity introduced by moderate levels of urbanisation may have a positive influence on some pollinators (Theodorou et al., 2016). Within urban areas, pollinator abundance and diversity is often highly varied as a result of the patchy distribution of these resources, with some greenspace sites rich in nesting and floral resources acting as key islands of habitat (Hülsmann et al., 2015; Kaluza et al., 2016; Theodorou et al., 2016).

As urban areas are expanding in Europe and globally, and pressures on ecosystems associated with increasing human populations and rates of consumption continue to rise (Shaker, 2015), national pollinator strategies (e.g. Defra, 2014) should be implemented that duly acknowledge and act on the importance of urban greenspace for pollinators (Baldock et al., 2015b; Hall et al., 2016). At a city scale, municipal planners should also enhance networks of high quality greenspace in support of pollinators, by targeting their often-limited resources in areas where they are most needed. These strategies can deliver 'win-wins' by also improving delivery of a range of ecosystem services, including opportunities to access nature, to the growing majority of people residing in urban areas (almost three quarters of people were reported to live in urban areas in the European Union (EU) in 2015 (EU, 2016, p.8)). However, trade-offs exist between biodiversity or species conservation and the demand for other land uses, functions and ecosystem services at a range of scales (Eigenbrod et al., 2009; Maes et al., 2012); for example, some greenspace users prefer short, 'neat' amenity grassland for recreation, which tends to be of low biodiversity value. Conservationists, local authorities, spatial planners and developers therefore need to work together to carefully plan, design and manage a biodiverse, multifunctional greenspace network. An evidence base is required to ensure that green infrastructure planning is taking measurable steps to improving urban areas for biodiversity, rather than acting as a 'tick box exercise' or an 'ecological trap' that meets policy obligations on paper, but divests funds away from more effective measures for biodiversity in reality (Garmendia et al., 2016). Action 5 of the 'EU Biodiversity Strategy to 2020' requires member states to 'Map and Assess the state of Ecosystems and their Services' (MAES), including biodiversity (Maes et al., 2016). However, the detailed information needed for this type of mapping exercise is often unavailable, particularly at a city-scale (Sandström et al., 2006). Practitioners would therefore benefit from relevant data and decision making tools that help them to assess the impact of plans on ecosystem services (e.g. De Ridder et al., 2004; Hansen and Pauleit, 2014; Łopucki and Kiersztyn, 2015; Vujić et al., 2016). For example, guidance from the MAES urban pilot project recommends using measures of pollinator abundance and the 'capacity for ecosystems to sustain insect pollination' as indicators for mapping insect pollination services (Maes et al., 2016, p. 79).

This study provides a modelling framework for informing strategic urban green infrastructure planning as a 'nature-based solution'. Nature-based solutions are 'actions which are inspired by, supported by or copied from nature …[that] aim to help societies address a variety of environmental, social and economic challenges in sustainable ways' (European Commission, 2015, p. 5). To meet these goals, our approach determines *what* actions should be taken to provide or improve a city's green infrastructure, and *where* to implement these actions across a city to maximise the benefits they provide to both pollinators and people. This adaptable framework can be applied to any taxonomic group or urban area of interest for which adequate data are available.

We use habitat suitability modelling (HSM; also commonly referred to as species distribution models (Elith and Leathwick, 2009; Franklin, 2009; Guisan and Zimmermann, 2000) to provide this evidence for two groups of wild insect pollinators (bumble bees and hoverflies). HSM typically involves identifying relationships between a species' known distribution, often obtained from organised surveys or existing records, and environmental factors over space. These models deliver spatially explicit, quantitative predictions of habitat suitability at a landscape scale, from which species distributions can be inferred. Understanding what urban features influence the distribution of particular taxa is key to informing greenspace strategies aimed at improving and protecting their habitats (Cox et al., 2016); multiscale HSM highlight important environmental correlates of a species' presence at a range of spatial scales, offering valuable insights into the species' habitat requirements and ecology (e.g. Bellamy et al., 2013). They can also be used to model the impact of potential changes, providing a useful tool for quantitatively appraising the biodiversity impact of alternative greenspace or housing development scenarios (Mortberg et al., 2007).

To identify areas where local people would benefit from improved green infrastructure, we focus on areas of high health deprivation using the health index of Scotland's Index of Multiple Deprivation data (The Scottish Government, 2012). It is now largely accepted that access to high quality greenspace and opportunities to interact with nature close to people's homes has a positive impact on health and well-being (Cox et al., 2017a, 2017b; Gascon et al., 2015; Hartig et al., 2014; Keniger et al., 2013; Maller et al., 2006). However, we know from the literature that residents of socioeconomically deprived areas tend to experience lower quality environmental conditions, including poor access to greenspace (Pearce et al., 2010). This is reflected in self-reports of greenspace satisfaction, which are most negative in the 15% most deprived areas in Scotland (TNS, 2014). Moreover, this report also showed that those people in the most deprived group are least likely to visit their local greenspace. This is problematic as greater greenspace exposure buffers the negative effect of income inequality on health outcomes (Mitchell and Popham, 2008). Research has also shown that environmental interventions in deprived areas improve frequency of use and environmental perceptions by local people (Ward Thompson et al., 2013). Therefore, these areas would ideally be prioritised for actions to provide pollinator-friendly, visually attractive green infrastructure as these could act as nature-based solutions to health deprivation. By overlaying these health target zones with priority pollinator improvement areas identified by the HSM, we highlight win-win opportunities where these enhancements would have both social and ecological benefits.

2. Materials and methods

2.1. Edinburgh case study

This work was done as part of GREEN SURGE, a collaborative EU