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Perceived species-richness in urban green spaces: Cues, accuracy and well-being impacts

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ABSTRACT

Evidence that urban green-space promotes health and well-being of urban residents is increasing. The role of biodiversity is unclear: perceived biodiversity may be important, but how accurately it is perceived and the factors influencing this accuracy are poorly understood. We use experimental perennial urban meadows in southern England to investigate the impact of creating biodiverse habitats on green-space users' i) physical and mental health, psychological well-being, ii) factors moderating health and well-being outcomes (site satisfaction and nature connectedness), and iii) perceived biodiversity. We explore whether 'nature dose' (time spent at a site) influences these relationships. We then assess whether green-space users can estimate botanical diversity accurately across meadow treatments differing in plant species richness and vegetation structure, and determine the environmental cues and personal characteristics associated with these estimates. Sites with experimental meadows did not increase respondents' perceptions of site level biodiversity, their self-rated physical and mental health or psychological well-being relative to control sites lacking meadows. However, there were significant associations between perceived site level biodiversity *per se*, and site satisfaction and feeling connected to nature. Moreover, we observed a positive association between nature dose and self-estimated mental health. We found that actual and perceived botanical richness in individual meadow plots were strongly positively correlated. Perceived richness was positively associated with vegetation height, evenness, and colourfulness suggesting that these are cues for estimating species richness. The accuracy of estimates varied, but respondents with higher levels of eco-centricity were more accurate than people who were less connected to nature.

1. Introduction

Whilst patterns of urbanisation range from sprawl to compaction, many cities around the globe are becoming denser, creating pressure on their green spaces (World Bank, 2015). It is thus increasingly important to maximise the capacity of urban green-spaces to support biodiversity and ecosystem services. Implementation of multifunctional 'nature based solutions' (van den Bosch & Ode Sang, 2017; Shanahan et al., 2015) helps to deliver these benefits. Such solutions typically increase biodiversity through habitat creation or ecological restoration schemes, whilst simultaneously providing additional benefits such as flood control, mitigation of urban heat islands (Bolund & Hunhammar, 1999) and atmospheric particulates and pollutants (Janhall, 2015), whilst also providing spaces for recreation and leisure (Chiesura, 2004). These nature based solutions can thus provide multiple benefits, including enhancements to human health, here broadly defined (following WHO, 2014) as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'. Thus defined, health includes psychological well-being which includes hedonic (feeling) and eudaimonic (meaning) dimensions (Ryff 1989; Ryff & Keyes, 1995; Dodge, Daly, Huyton, & Sanders, 2012; WHO, 2014).

In terms of physical and mental health, exposure to urban green space reduces disease, obesity and mental illness through mechanisms including the promotion of physical exercise (Schipperijn et al., 2017), as well as reducing stress through opportunities for psychological restoration (Irvine, Warber, Devine-Wright, & Gaston, 2013). Green spaces can improve well-being through increased personal identity by strengthening place attachment (Zhang, van Dijk, Tang & van den Berg, 2015), and increasing social interaction and cohesion (Mukerjee, 2013), a recognised component of psychological well-being (Ryff 1989; Ryff & Keyes, 1995).

Relationships between green-space exposure and well-being can be moderated by other factors within the social environment (Lachowycz & Jones, 2013). Satisfaction with the quality of local green-space is one

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such moderator that is key to the mental well-being of urban dwellers and relates to satisfaction with the wider neighbourhood (Campbell, Bodley and Berkeley, 2007). There is, for example, a causal relationship between higher green-space satisfaction and greater levels of attachment to the local neighbourhood, which correlates positively with mental health Zhang et al. (2015).

Engagement with green space can foster emotional affinities with nature (Beery & Wolf-Watz, 2014), and a growing evidence base demonstrates nature connectedness can moderate positive health and well-being outcomes (Capaldi, Dopko & Zelenski, 2014; Zelenski and Nisbet, 2014). These benefits include greater life satisfaction (Mayer and Frantz, 2004), increased eudaimonic well-being (Capaldi et al., 2014), and greater subjective well-being (Nisbet et al., 2011). Increased connection to nature can also help promote the development of ecocentric or pro-environmental behaviour (Beery & Wolf-Watz, 2014; Coldwell and Evans, 2017), which can be of mutual benefit to both humans and wildlife.

Exposure to green-space can thus promote enhanced physical and mental health and psychological well-being, through a number of pathways and 'moderators' (Lachowycz & Jones 2013). The magnitude of these benefits may increase with the amount of exposure to green-space through a dose-response curve (Keniger, Gaston, Irvine, & Fuller, 2013). In other words the magnitude of the 'dose of nature' can be positively associated with the extent of health and well-being benefits (Shanahan et al., 2016). Even relatively short but frequent exposures to green-spaces can increase self-esteem and restoration (Barton and Pretty, 2010), ameliorate depression and high blood pressure and promote greater social cohesion and an increased connection with nature (Cox et al., 2017; Shanahan et al., 2016).

Despite a large number of studies demonstrating positive impacts of green space on human health and well-being outcomes, most have not empirically investigated the role of biodiversity in these outcomes (Sandifer et al., 2015). It is thus unclear whether nature based solutions and urban green-space management that focus on increasing biodiversity will enhance human health and well-being beyond that provided by existing, but less biodiverse, green-space. Evidence is emerging that site level biodiversity is positively associated with psychological well-being, perhaps because biodiverse sites provide greater opportunity for reflection (Fuller et al., 2007). These beneficial impacts may depend on people's perceptions of biodiversity and there is contradictory evidence regarding how accurately the general public can assess biodiversity (Fuller et al., 2007; Dallimer et al., 2012). Thus the potential for enhanced health and well-being impacts through nature based solutions may depend on people's ability to perceive the increased biodiversity generated by these interventions. Socio-demographic and life-style factors may influence peoples' perceptions of biodiversity, e.g. older people may have accumulated more knowledge about biodiversity due to greater exposure to biodiverse environments (which have since become rarer), more time to accumulate knowledge, or perhaps greater interest in biodiversity. Initial work suggests that people with some degree of environmental awareness are generally more knowledgeable about biodiversity and better at assessing species richness, but much more work remains to be done in regard to which factors influence peoples biodiversity knowledge (Lindemann-Matthies & Bose, 2008; Coldwell & Evans2017). It is thus important to quantify links between biodiversity, health and well-being and to improve understanding of the cues people use to estimate biodiversity, and which factors influence this.

Currently, much existing urban green space is dominated by amenity grassland, which is regularly mown to create a short sward, thus limiting its biodiversity value (Smith, Broyles, Lazleer & Fellowes, 2015). An increasingly advocated nature based solution is to convert amenity grassland to urban meadows that can enhance biodiversity and delivery of a wider range of ecosystem services (Smith et al., 2015). We use a novel, large scale manipulation experiment in two towns in Southern England that converted urban amenity grassland to urban meadows to explore the health and well-being impacts of this habitat creation scheme. We have previously demonstrated that for many residents meadow vegetation has greater aesthetic value, especially when sown with more plant species (Southon, Jorgensen, Dunnett, Hoyle & Evans, 2017). Here, we use an experimental test to assess if i) meadow creation and perceived biodiversity are associated with physical and mental health, psychological well-being and moderators of well-being (site satisfaction and connectedness to nature) and ii) if people can accurately assess biodiversity and the factors that influence this ability.

2. Methods

2.1. Experimental meadow creation and design

Meadows were established in five mown grassland sites within residential areas of Bedford and Luton, Southern England (Fig. S1). One site is excluded from analysis as successful establishment occurred after phase 1 data collection (see below). We used the Multiple Index of Deprivation (Office for National Statistics 2015) of the lower super output area surrounding each site as a socio-economic indicator, which ranged from 5 (amongst the 10% least deprived neighbourhoods in England) to 39 (amongst the 20% most deprived neighbourhoods). Each experimental site was paired with a nearby control site that was similar in its size, vegetation features, type of surrounding residential development and deprivation index (Fig. S2).

Meadow treatments spanned two axes of variation: plant species richness (low, medium and high) and structural diversity (short, medium and tall), generating nine types of meadows. A full suite of nine meadow treatments were established at each site except at two where we used fewer treatments due to restricted space (Goldington Green and Brickhill Heights; Table S1). Plant species richness was controlled by sowing different numbers of native perennial species with different proportions of grasses and forbs; some additional variation arose from colonisation by other species. Structure was partly determined through plant selection but primarily managed by cutting regimes (Southon et al., 2017). Seed mixes were randomly allocated to each standardised rectangular plot (250 m^2) that were separated by 5 m of original short mown turf (Table S2). Meadow plots occupied a small proportion of each site (on average 8%: range 4–12%), but were located in frequently visited areas, and had a dramatic visual impact on the landscape during their first and second years (i.e. throughout the duration of this study; Fig. S3).

2.2. Questionnaire overview

We used a two- phased approach to assess impacts of urban meadows on green-space users. Phase 1 questionnaires assessed respondents' perceived species richness within each green-space (four experimental sites and corresponding control sites that lacked meadows), mental and physical health and psychological well-being (using a range of attitudinal statements and well established health scales, see below for more details). Phase 2 questionnaires focused on perceived species richness in individual meadows and perceived attributes of each plot (e.g. colourfulness, see below for more details) that might be used as cues when estimating species richness and how respondents' socio-demographic and other factors influenced perceived richness. Perceived species richness was compared to actual species richness calculated using robust botanical survey methods and less formal approaches that more closely matched how respondents experienced the plots.

2.3. Phase 1: meadow creation – site level impacts

Phase 1 questionnaires (30 per site; n = 240) were conducted during the first year of meadow creation when plots were similar to their 2nd year appearance but not fully developed (Fig. S3). Potential respondents (all visitors to the site over 18 years of age) were