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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 eco-centric 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 approached whenever an interviewer became available. Most respondents lived in close proximity to the site, e.g. the shortest walkable route from respondents' homes to the sites was ≤ 1 mile (1.6 km) for 79% of respondents and ≤ 2 miles (3.2 km) for 91% of respondents (data obtained using walking routes determined by google maps from respondents' home postcodes).

Respondents were asked to rate their physical health compared to other people of their age on a five point Likert scale (1 = very poor; 5 = excellent; following Snead (2007)). To explore the feeling and functioning aspects of positive mental well-being we used the Short Warwick-Edinburgh Mental Well-being Scale (SWEMWBS; Stewart-Brown et al., 2011). This scale comprises seven questions, such as "I've been dealing with problems well", scored on a five point Likert scale based on the respondent's experience over the last two weeks, with responses ranging from 'all of the time' to 'none of the time'. We summed the responses across all seven questions to derive a single SWEMWBS score ranging from 7 (none of the time selected for each question, indicating low mental health) to 35 (indicating high mental health; Stewart-Brown et al., 2011).

Respondents were asked to indicate their level of agreement with 24 attitudinal statements related to the restorative and affective aspects of site use on a five point Likert scale (1 = strongly disagree; 5 = strongly agree). These statements included 14 items developed by Fuller, Irvine, Devine-Wright, Warren, and Gaston (2007) based on attention restoration theory, opportunities for reflection (derived from Herzog, Black, Fountaine, & Knotts, 1997; Kaplan & Kaplan, 1989) and elements of emotional attachment to green-space (e.g. continuity with the past and personal identity, derived from Manzo, 2003; Patterson & Williams, 2005). We devised 10 additional novel statements derived from nature connectedness and site satisfaction literature (Table S3). We used factor analysis in SPSS (version 22) with an oblique rotation method (oblimin) to determine groups of statements that related to a single underlying dimension. Following Tabachnick & Fidell (2001), factor structures were based on loadings with absolute values ≥ 0.40 (any item cross-loading on two or more factors at +/− 0.40 level or higher was dropped), and Cronbach alpha coefficients ≥ 0.60. Five factors were extracted (for loadings, eigenvalues and tests for internal consistency see Table S4), three related to psychological well-being dimensions of green-space use (place attachment, continuity with the past and reflection), and two additional moderating factors i.e. site satisfaction and connection to nature. Responses to individual statements loading on each factor were averaged to generate five continuously distributed psychological well-being or moderator variables.

We used open ended questions to record how frequently respondents visited the site in a typical fortnight and the typical duration of these visits. These were combined to calculate site use (total time spent at the site) to explore dose-dependent relationships between exposure to green-space and our response variables.

We collected data on respondents' age, income, employment status, education, postcode (from which we obtained the Index of Multiple Deprivation), ethnicity and gender. We used Categorical Principal Components Analysis (CATPCA) in SPSS (version 22) to assess co-variation in socio-economic variables (i.e. respondents' income, educational attainment, employment status, ethnicity and multiple deprivation index). Two axes were recovered that together accounted for 58% of the variation. Variables loading positively onto the first axis (eigenvalue 1.68) were educational attainment (factor score of 0.73), employment status (0.68) and income (0.77); we term this axis socio-economic status. Variables loading positively onto the second axis (eigenvalue 1.23) were the multiple deprivation index (0.69) and ethnicity (0.68); we term this axis the ethnicity-deprivation index.

Following Dallimer et al. (2012) and Fuller et al. (2007), perceived species richness was assessed by asking respondents to estimate (based purely on their subjective experience of the site at the time) how many different types of birds, butterflies and plants occurred at the site (i.e. at experimental sites including, but not limited to, the meadow plots). Responses were made on a seven point scale (< 5, 5–15, 16–30, 31–60, 61–100, 101–150, 151–200); we used the same scale for each taxonomic group to prevent respondents inferring, from the response options, differences in species richness between taxonomic groups. The range of values was selected to represent the expected range in species richness in urban parks based on survey work conducted in the focal region. Perceived species richness was derived by calculating the midpoint of each interval scale for the number of perceived bird, butterfly and plant species. A measure of total perceived species richness was calculated by summing responses to all three taxonomic groups across these midpoints.

2.4. Data analysis–study population

All statistical analyses were conducted in R version 3.2.1. We assessed if respondents' socio-demographic traits varied across sites using Kruskal Wallis tests for continuous variables (age, socio-economic traits and ethnicity-deprivation) and Chi Squared tests for binary variables, i.e. gender.

2.4.1. Data analysis phase 1: meadow creation–site level impacts and perceptions

Our general approach was to assess if meadow establishment influenced a range of outcome measures linked to health and well-being, i.e. self-estimated mental and physical health, self-estimated psychological well-being, and moderating factors of connection to nature and site satisfaction. We did this by comparing respondents' outcome metrics at sites where meadows were created with those from control sites without meadows, whilst taking into account socio-demographic factors, and site use (total time spent at the site in a typical fortnight) to take dose-dependent relationships into account. Preliminary analyses included the interaction between treatment (meadow or control site) and site use, but these interaction terms were insignificant for all outcome variables so we only report results of models without interaction terms. We follow Whittingham, Stephens, Bradbury, and Freckleton (2006) and report the results of full models only, and use Nakagawa & Schielzeth's R^2 (Nakagawa & Schielzeth 2013; Johnson 2014) to quantify the explanatory capacity of this and subsequent models.

To determine if meadow creation influenced perceived site level species richness we modelled it (running separate models for total biodiversity, and for each taxonomic group) as a function of treatment (meadow or control site) with gender (a binary fixed effect), age, socio-economic status, ethnicity-deprivation index, site use (as continuous variables) and site (as a random effect) using linear mixed effects models (package nlme; Pinheiro, Bates, Debroy, Sarkar, & R Core Team, 2016) in R version 3.2.1.

To explore relationships between health and well-being and the establishment of the meadow plots at the site level we modelled each respondent's self-estimated physical health and mental health scores, psychological well-being, (i.e. scores on the derived well-being factors place attachment, continuity with the past and reflection), moderating factors of well-being (i.e. scores derived on the factors of connection to nature and site satisfaction) and perceived species richness (running separate models for total biodiversity, and for each taxonomic group) as a function of treatment (meadow or control). We controlled for gender, age, socio-economic status, ethnicity-deprivation index, site use and included site as a random effect. We used linear mixed effects models constructed using the nlme package (Pinheiro et al., 2016) in R (version 3.2.1).

To determine whether health and well-being were associated with perceived species richness at the site level we modelled respondents' (n = 240) self-estimated physical health and mental health scores, psychological well-being (separate models for place attachment, continuity with the past and reflection), and their moderating factors of connection to nature and site satisfaction as a function of perceived species richness, gender, age, socio-economic status, ethnicity-deprivation index, site use and site (as a random effect) using linear mixed effects models in the nlme package (R version 3.2.1). Separate models were run in relation to perceived bird, butterfly, plant richness and total species richness. Preliminary analyses included the interaction between site use and perceived species richness but these were always non-significant so we only report results of models containing main effects.

2.5. Phase 2: perceived species richness of the meadow plots themselves–accuracy, cues to assessment and influence of respondents' characteristics

2.5.1. Botanical surveys

Botanical surveys were conducted in five $1m^2$ quadrats located within each meadow treatment from July-August 2014, i.e. the second season after sowing. We recorded actual plant species richness (i.e. the total number of species recorded from all quadrats); plant percent cover abundance scale (using the DOMIN scale) and vegetation height per quadrat (based upon 4 measurements, at random locations, per quadrat). To represent how members of the public were likely to view the plots (referred to as casual visual surveys) an experienced botanist recorded species richness from the perimeter of the plots. For each species we recorded relative abundance (using the DAFOR scale) and percentage flowering cover.

We thus measured actual species richness in full botanical surveys and casual visual surveys (i.e. species richness observed from the perimeter of the plots). From the full botanical surveys we derived the following additional metrics, which were used to assess cues used by respondents when estimating species richness: actual forb: grass ratio (the number of forb species to grass species), vegetation height and vegetation evenness (using the Shannon index (Beals, Gross & Harrell, 2000) which provides a measure of whether vegetation cover is distributed evenly across species or if a few of the species present dominate. From the casual visual surveys we derived the following metrics: visual forb: grass ratio (the number of forb species to grass species observable from the perimeter of the plots), visual vegetation evenness (Shannon index), and visual abundance of flowers (i.e. the percentage cover of flowering forbs in the plot, as viewed from its perimeter).

2.5.2. Questionnaires

A second set of questionnaires ($n = 120$) was conducted at the same time as the botanical surveys, to a) assess respondents' abilities to perceive plant species richness within the experimental plots, b) identify whether respondents' characteristics influence their ability to perceive species richness accurately and c) gain more information about cues that respondents may use when assessing richness. The latter was based upon responses to three attitudinal statements "I think this plot looks colourful/natural/weedy" on a five point Likert scale (1 = strongly disagree; 5 = strongly agree).

We collected data on a range of metrics to test the hypothesis that respondents with greater eco-centricity would perceive species richness more accurately. These metrics were i) use of the countryside (how many times they visit within a fortnight); ii) botanical knowledge (respondents were asked to identify nine common plant species from photographs (see Table S6) and iii) support for wildlife (assessed by asking respondents if they had wildlife features in their garden or would like to see them established at the site, see Table S6). We also obtained data on respondents' age, income, employment status, educational attainments, postcode (from which the Multiple Index of Deprivation was obtained) and gender.

2.5.3. Data analysis phase 2

We conducted a Principal Component Analysis (PCA) in SPSS (version 22) to assess co-variation within our three measures of eco-centricity (countryside visit frequency, botanical knowledge and support for wildlife). One axis was recovered, which accounted for 43% of the total variation (eigenvalue of 1.28), with strong positive loadings for wildlife support (0.68), countryside visit frequency (0.66) and plant identification (0.62); we term this axis eco-centricity. We used Categorical Principal Components Analysis to assess co-variation on the socio-economic variables and recovered the same axes as in Phase 1 (socio-economic status (eigenvalue 1.61) and ethnicity-deprivation (eigenvalue 1.48)).

To assess correlations between perceived and actual species richness we used linear mixed effects models (package nlme; R version 3.2.1) to model a) perceived number of plant species as a function of actual species richness and b) perceived number of plant species as a function of casual visual species richness (i.e. that observed from the perimeter of the plots). In both models, we included person as a random effect as each respondent assessed multiple plots.

To assess which vegetation features other than actual species richness are associated with perceived species richness we used linear mixed effects models (package nlme; R version 3.2.1) to model perceived number of plant species as a function of the actual forb to grass ratio, actual species evenness (i.e. calculated from the full botanical survey), visual forb to grass ratio, visual species evenness (i.e. calculated from the casual visual botanical survey), flowering abundance (from the casual visual botanical survey), and individual respondents' perceptions of colourfulness, weediness, and naturalness of the focal plot. Person was included as a random factor. To facilitate interpreting effect of each predictor they were standardised (using z scores) prior to analysis.

To assess whether personal characteristics influenced respondents' ability to perceive species richness accurately we calculated the absolute percentage difference between each person's perceived species richness scores for each meadow treatment and actual species richness (to provide a more conservative test than comparisons with casual visual species richness). The use of an absolute difference enabled us to address our core question of which respondent characteristics are associated with the accuracy of species richness estimates, and to average percentage differences across multiple meadow treatments without over and under-estimates cancelling each other out. The mean absolute percentage difference was modelled as a function of site use, gender, age, socio-economic status, ethnicity-deprivation, eco-centricity and site (as a random effect) using linear mixed effects models (package nlme; R version 3.2.1).

3. Results

3.1. Study population

The socio-demographic characteristics of each survey population are reported in Table S5. Phase 1 and phase 2 survey respondents' socio-demographic characteristics did not vary significantly across sites, with the exception of ethnicity-deprivation scores (Phase 1: $P = 0.09$; Phase 2: $P < 0.006$). We expected this socio-demographic trait to vary across the meadow intervention sites as each site is surrounded by divergent socio-demographic groups (as assessed by multiple deprivation indices) and experimental sites were selected to represent diverse housing areas. Visitors interviewed during Phase 1 typically spent between 20 and 60 min at the site, and visited between 8 and 12 times per fortnight.

3.2. Phase 1: meadow creation –site level impacts

In the first year of meadow creation we found no evidence that perceived species richness of plants, butterflies or birds, or total perceived richness summed across these groups was higher at our experimental treatment sites, where meadows were created, compared with control sites without urban meadows (Table 1). These analyses took age, gender, socio-economic status and ethnicity-deprivation and site use into account; there was no consistent evidence that these

Table 1

Results of linear mixed effects models of perceived species richness as a function of the establishment of experimental meadow treatments and socio-demographic variables. Data reported are parameter estimates, the 95% confidence intervals and P values. Parameter estimates for treatment are expressed relative to control sites (set at zero), and for gender are expressed relative to women (set at zero). Goodness of fit was estimated using a Pseudo R^2 approach as outlined by Nakagawa & Schielzeth (2013) and Johnson (2014).

Response	Meadow treatment			Age			Gender			Socio-economic status			Ethnicity-deprivation			Site Use			Model R^2
	Est	CI	*P*	Est	CI	*P*	Est	CI	*P*	Est	CI	*P*	Est	CI	*P*	Est	CI	*P*	
Perceived total species richness	6.55	−35.20 to 48.29	0.77	−0.44	−1.31 to 0.44	0.33	−13.1	−37.33 to 11.08	0.29	−12.99	−26.51 to 0.53	0.06	−3.99	−17.04 to 9.06	0.55	0.01	−0.01 to 0.03	0.42	0.15
Perceived plant richness	2.58	−19.58 to 24.74	0.83	−0.45	−1.05 to 0.15	0.14	−4.76	−21.10 to 11.58	0.57	−9.40	−18.60 to −0.19	0.05	−1.56	−10.43 to 7.31	0.73	0.001	−0.02 to 0.02	0.92	0.08
Perceived bird species richness	−0.30	−11.98 to 11.38	0.96	0.08	−0.16 to 0.32	0.53	−3.80	−10.43 to 2.83	0.26	−2.46	−6.16 to 1.24	0.20	−1.20	−4.77 to 2.37	0.51	0.01	−0.001 to 0.01	0.12	0.17
Perceived butterfly species richness	4.42	−5.75 to 14.58	0.43	−0.02	−0.29 to 0.24	0.86	−3.54	−10.69 to 3.62	0.33	−0.64	−4.67 to 3.38	0.75	−0.53	−4.41 to 3.35	0.79	0.005	−0.003 to 0.01	0.22	0.09

Table 2

Results of linear mixed effects models of physical and mental health measures and psychological well–being as a function of the establishment of experimental meadow treatments and socio–demographic variables. Data reported are parameter estimates, the 95% confidence intervals and P values. Parameter estimates for treatment are expressed relative to control sites (set at zero), and for gender are expressed relative to women (set at zero). Goodness of fit was estimated using a Pseudo R^2 approach as outlined by Nakagawa & Schielzeth (2013) and Johnson (2014).

Response	Meadow treatment			Age			Gender			Socio − economic status			Ethnicity − deprivation			Site Use			Model
	Est	CI	P	Est	CI	P	Est	CI	P	Est	CI	P	Est	CI	P	Est	CI	P	R^2
Attachment	−0.08	−0.27 to 0.11	0.43	0.005	−0.001 to 0.01	0.12	−0.001	−0.16 to 0.16	0.99	0.06	−0.03 to 0.15	0.22	0.05	−0.04 to 0.14	0.29	0.00001	−0.0002 to 0.0002	0.89	0.05
Site satisfaction	0.03	−0.11 to 0.16	0.71	−0.0003	−0.004 to 0.004	0.88	−0.01	−0.12 to 0.09	0.80	0.03	−0.03 to 0.09	0.36	0.01	−0.05 to 0.07	0.67	−0.00005	−0.0002 to 0.0001	0.39	0.05
Continuity with the past	−0.06	−0.27 to 0.15	0.59	−0.25	−0.46 to −0.03	0.03	0.01	0.002 to 0.02	0.02	−0.02	−0.15 to 0.10	0.70	0.08	−0.04 to 0.20	0.19	0.0003	0.00003 to 0.0005	0.03	0.13
Reflection	−0.26	−0.51 to −0.01	0.08	0.01	−0.19 to 0.20	0.95	0.01	0.0001 to 0.01	0.05	0.08	−0.03 to 0.19	0.18	0.11	−0.001 to 0.21	0.05	0.001	0.001 to 0.001	0.41	0.13
Connection to nature	0.13	−0.07 to 0.33	0.25	0.01	0.003 to 0.02	0.01	−0.07	−0.27 to 0.14	0.51	0.001	−0.12 to 0.12	0.99	0.14	0.03 to 0.25	0.02	0.0002	−0.00004 to 0.0004	0.12	0.10
Mental health	0.60	−0.94 to 2.14	0.47	0.01	−0.04 to 0.07	0.62	0.83	−0.69 to 2.36	0.29	−0.34	−1.21 to 0.54	0.45	0.42	−0.42 to 1.26	0.33	−0.001	−0.003 to 0.0003	0.10	0.06
Physical health	0.05	−0.19 to 0.29	0.71	−0.17	−0.42 to 0.07	0.17	−0.001	−0.01 to 0.01	0.91	0.12	−0.02 to 0.27	0.09	−0.004	−0.14 to 0.13	0.96	0.0001	−0.0002 to 0.0003	0.62	0.05

Table 3

Results of linear mixed effects models of physical and mental health measures and psychological well–being as a function of perceived biodiversity and socio–demographic variables. Data reported are parameter estimates, the 95% confidence intervals and P values. Parameter estimates for treatment are expressed relative to control sites (set at zero), and for gender are expressed relative to women (set at zero). Goodness of fit was estimated using a Pseudo R^2 approach as outlined by Nakagawa & Schielzeth (2013) and Johnson (2014).

Taxa	Perceived species richness		Age		Gender		Socio − economic status		Ethnicity − deprivation		Site Use		Model
	Est (95% CI)	*P*	Est (95% CI)	*P*	Est (95% CI)	*P*	Est (95% CI)	*P*	Est (95% CI)	*P*	Est (95% CI)	*P*	R^2
	Attachment												
All species	0.0003 (−0.001 to 0.001)	0.60	0.005 (−0.001 to 0.01)	0.12	−0.01 (−0.17 to 0.15)	0.92	0.06 (−0.03 to 0.16)	0.20	0.05 (−0.04 to 0.14)	0.25	0.0002 (−0.0001 to 0.0002)	0.83	0.05
Plants	0.0005 (−0.001 to 0.002)	0.57	0.01 (−0.001 to 0.01)	0.11	−0.01 (−0.17 to 0.15)	0.91	0.06 (−0.03 to 0.16)	0.19	−0.05 (−0.04 to 0.14)	0.25	0.00002 (−0.0001 to 0.0002)	0.80	0.05
Birds	0.001 (−0.003 to 0.01)	0.55	0.005 (−0.001 to 0.01)	0.14	−0.01 (−0.17 to 0.15)	0.93	0.06 (−0.03 to 0.15)	0.20	0.05 (−0.04 to 0.14)	0.25	0.00001 (−0.0002 to 0.0002)	0.87	0.05
Butterflies	−0.0001 (−0.004 to 0.004)	0.94	0.005 (−0.001 to 0.01)	0.12	−0.01 (−0.17 to 0.15)	0.89	0.06 (−0.03 to 0.15)	0.22	0.05 (−0.04 to 0.14)	0.26	0.00002 (−0.0001 to 0.0002)	0.80	0.05
	Site satisfaction												
All species	0.001 (0.001 to 0.002)	0.0002	0.0001 (−0.004 to 0.004)	0.95	0.003 (−0.10 to 0.11)	0.96	0.05 (−0.01 to 0.10)	0.14	0.02 (−0.04 to 0.07)	0.57	−0.0001 (−0.0002 to 0.00004)	0.21	0.13
Plants	0.002 (0.001 to 0.003)	0.002	0.0004 (−0.004 to 0.004)	0.84	−0.004 (−0.11 to 0.10)	0.94	0.04 (−0.02 to 0.11)	0.15	0.02 (−0.04 to 0.07)	0.60	−0.0001 (−0.0002 to 0.0001)	0.33	0.10
Birds	0.003 (0.0002 to 0.01)	0.04	−0.001 (−0.005 to 0.003)	0.75	−0.001 (−0.11 to 0.11)	0.99	0.04 (−0.03 to 0.10)	0.26	0.02 (−0.04 to 0.07)	0.61	−0.0001 (−0.0002 to 0.00004)	0.22	0.07
Butterflies	0.005 (0.002 to 0.01)	0.0001	−0.0003 (−0.004 to 0.003)	0.86	0.005 (−0.10 to 0.11)	0.93	0.03 (−0.03 to 0.09)	0.30	0.02 (−0.04 to 0.07)	0.54	−0.0001 (−0.0002 to 0.00003)	0.16	0.11
	Continuity with the past												
All species	−0.0001 (−0.002 to 0.001)	0.91	0.01 (0.002 to 0.02)	0.02	−0.26 (−0.47 to −0.05)	0.02	−0.03 (−0.15 to 0.10)	0.70	0.08 (−0.04 to 0.20)	0.17	0.0003 (−0.002 to 0.003)	0.02	0.13
Plants	0.0002 (−0.002 to 0.002)	0.88	0.01 (0.002 to 0.02)	0.01	−0.26 (−0.47 to −0.05)	0.02	−0.02 (−0.15 to 0.10)	0.72	0.08 (−0.04 to 0.20)	0.17	0.0003 (0.00004 to 0.0005)	0.02	0.13
Birds	−0.0001 (−0.01 to 0.004)	0.68	0.01 (0.002 to 0.02)	0.01	−0.26 (−0.47 to −0.05)	0.02	−0.03 (−0.15 to 0.10)	0.68	0.08 (−0.04 to 0.20)	0.17	0.0003 (0.00005 to 0.001)	0.02	0.13
Butterflies	−0.0001 (−0.005 to 0.005)	0.91	0.01 (0.003 to 0.02)	0.01	−0.27 (−0.48 to −0.05)	0.02	−0.01 (−0.13 to 0.12)	0.93	0.09 (−0.03 to 0.21)	0.13			0.12
	Reflection												
All species	0.0004 (−0.001 to 0.002)	0.61	0.007 (0.0001 to 0.01)	0.05	0.001 (−0.20 to 0.20)	1.00	0.08 (−0.03 to 0.20)	0.15	0.11 (0.004 to 0.22)	0.04	0.0001 (−0.0001 to 0.0003)	0.35	0.12
Plants	0.001 (−0.001 to 0.003)	0.23	0.01 (0.001 to 0.02)	0.04	0.003 (−0.20 to 0.20)	0.98	0.09 (−0.02 to 0.21)	0.12	0.11 (−0.0001 to 0.0003)	0.33	0.001 (−0.0001 to 0.0003)	0.33	0.13
Birds	−0.00004 (−0.01 to 0.005)	0.89	0.01 (0.0003 to 0.01)	0.05	−0.01 (−0.21 to 0.20)	0.96	0.08 (−0.03 to 0.22)	0.17	0.11 (0.003 to 0.22)	0.05	0.0001 (−0.0001 to 0.0003)	0.32	0.12
Butterflies	−0.002 (−0.01 to 0.003)	0.41	0.01 (0.000 to 0.01)	0.05	−0.01 (−0.21 to 0.19)	0.92	0.08 (−0.03 to 0.19)	0.17	0.11 (0.002 to 0.22)	0.05	0.0001 (−0.0001 to 0.0003)	0.29	0.12
	Connection to nature												
All species	0.001 (0.0001 to 0.003)	0.03	0.01 (0.003 to 0.02)	0.01	−0.04 (−0.23 to 0.17)	0.76	0.02 (−0.10 to 0.13)	0.79	0.13 (0.02 to 0.25)	0.02	0.0001 (−0.0001 to 0.0003)	0.23	0.12
Plants	0.003 (0.001 to 0.005)	0.01	0.01 (0.004 to 0.02)	0.003	−0.04 (−0.24 to 0.16)	0.71	0.02 (−0.09 to 0.14)	0.71	0.14 (0.02 to 0.25)	0.02	0.0001 (−0.0001 to 0.0004)	0.18	0.13
Birds	0.002 (−0.003 to 0.01)	0.47	0.01 (0.003 to 0.02)	0.01	−0.04 (−0.24 to 0.17)	0.72	0.003 (−0.12 to 0.12)	0.95	0.13 (0.02 to 0.25)	0.02	0.0001 (−0.0001 to 0.0004)	0.21	0.09
Butterflies	0.002 (−0.002 to 0.01)	0.32	0.01 (0.003 to 0.02)	0.01	−0.04 (−0.24 to 0.17)	0.72	0.001 (−0.12 to 0.12)	0.99	0.13 (0.02 to 0.25)	0.02	0.0001 (−0.0001 to 0.0004)	0.20	0.10
	Mental health												
All species	−0.01 (−0.02 to 0.0003)	0.20	−0.02 (−0.07 to 0.04)	0.53	−0.93 (−2.42 to 0.55)	0.22	0.20 (−0.67 to 1.08)	0.65	−0.39 (−1.23 to 0.44)	0.36	0.002 (−0.0001 to 0.0003)	0.05	0.06
Plants	−0.0001(−0.02 to 0.01)	0.92	−0.02 (−0.07 to 0.04)	0.56	−0.89 (−2.38 to 0.60)	0.24	0.27 (−1.15 to 0.62)	0.56	−0.38 (−1.22 to 0.45)	0.37	0.001 (−0.0001 to 0.003)	0.07	0.05
Birds	−0.03 (−0.07 to 0.003)	0.08	−0.01 (−0.07 to 0.04)	0.68	−0.98 (−2.47 to 0.50)	0.20	0.22 (−0.65 to 1.08)	0.62	−0.40 (−1.23 to 0.43)	0.35	0.002 (−0.0001 to 0.003)	0.04	0.07
Butterflies	−0.04 (0.08 to 0.01)	0.01	−0.02 (−0.07 to 0.04)	0.58	−0.99 (−2.45 to 0.47)	0.19	0.26 (−0.59 to 1.12)	0.55	−0.38 (−0.44 to 1.20)	0.36	−0.002 (−0.0001 to −0.003)	0.04	0.08
	Physical health												
All species	0.0005 (−0.001 to 0.002)	0.60	−0.001 (−0.01 to 0.01)	0.91	−0.16 (−0.40 to 0.08)	0.20	0.13 (−0.01 to 0.27)	0.08	−0.01 (−0.14 to 0.13)	0.93	0.001 (−0.0002 to 0.0003)	0.70	0.05
Plants	0.001 (−0.002 to 0.003)	0.55	−0.0003 (−0.01 to 0.01)	0.95	−0.16 (−0.41 to 0.08)	0.19	0.13 (−0.01 to 0.28)	0.08	−0.01 (−0.14 to 0.13)	0.93	0.0001 (−0.0002 to 0.0003)	0.67	0.05
Birds	0.0002 (−0.01 to 0.01)	0.94	−0.001 (−0.01 to 0.01)	0.89	−0.16 (−0.41 to 0.08)	0.19	0.12 (−0.02 to 0.27)	0.09	−0.01 (−0.14 to 0.13)	0.93	0.0001 (−0.0002 to 0.0003)	0.67	0.05
Butterflies	0.001 (−0.005 to 0.01)	0.73	−0.001 (−0.01 to 0.01)	0.90	−0.16 (−0.41 to 0.08)	0.20	0.12 (−0.02 to 0.27)	0.09	−0.01 (−0.14 to 0.13)	0.93	0.0001 (−0.0002 to 0.0003)	0.69	0.05

characteristics influenced perceived species richness (Table 1).

There was no evidence of positive associations between meadow creation and self-estimated physical and mental health or psychological well-being. However women, older people and those who used the site most were significantly more likely to report increased continuity with the past. Meadow creation had no relation to site satisfaction or connection to nature, but older people and those representing higher ethnicity-deprivation were more likely to report greater connection to nature (Table 2).

Health and well-being metrics were not related to perceived species richness, but perceived species richness did influence factors that can moderate health and well-being outcomes. Site satisfaction was positively associated with all perceived species richness metrics (total richness and that of plants, butterflies and birds; Table 3). Respondents' connection to nature was positively correlated with perceived total species richness and plant species richness (Table 3). Self-estimated mental health and continuity with the past tended to correlate positively with site use (Table 3). Older people experienced greater connection to nature, reflection and continuity with the past (Tables 2 and 3); women experienced greater continuity with the past than men (Tables 2 and 3); respondents with higher ethnicity-deprivation scores also experienced greater connection to nature and reflection (Tables 2 and 3) and people who used the site most frequently experienced greater continuity with the past.

3.3. Phase 2: perceived species richness of meadow plots

Perceived plant species richness within individual meadow treatments was positively correlated with actual richness recorded in full botanical surveys and casual surveys that more closely matched how the general public viewed the plots (full surveys: $R^2 = 0.57$; parameter estimate: 0.013 (95% CIs 0.021-0.041); $P < 0.001$; casual surveys: $R^2 = 0.59$; parameter estimate: 0.030 (95% CIs 0.021–0.041); $P < 0.001$). Actual species richness observed in complete and casual botanical surveys were positively correlated with each other (Fig. S4).

The accuracy of perceived species richness (i.e. a respondent's mean absolute percentage difference between perceived and actual plant species richness in the complete botanical surveys) was significantly smaller, and close to zero, for respondents with the highest eco-centricity scores (Fig. 1). This is regardless of whether perceived richness is compared to actual species richness in full botanical surveys or the casual visual surveys (Table 4). In both analyses we find no evidence that site use, gender, age, socio-economic status or ethnicity-deprivation influenced the accuracy of perceived species richness estimates (Table 4).

Table 4
Results of linear mixed effects model of the absolute% difference between **(A)** actual botanical species richness and **(B)** casual visual botanical species richness and an individuals' perceived species richness in treatment plots as a function of respondents socio–demographic status, site use and eco−centricity and incorporating site as a random effect. Data reported are parameter estimates, their 95% confidence intervals and P values. Model $R^2 = 0.93$. This was estimated using a Pseudo R^2 approach as outlined by Nakagawa & Schielzeth (2013) and Johnson (2014).

Person characteristics	Parameter estimate	Lower CI	Upper CI	*P* value
(A) Actual botanical species richness				
Site use	−0.03	−0.07	0.01	0.19
Gender (male)	−4.43	−19.30	10.44	0.56
Age	−0.07	−0.74	0.59	0.83
Socio–economic status	−2.08	−7.00	11.17	0.65
Ethnicity–deprivation	−5.06	−14.85	4.72	0.31
Eco–centricity	−9.86	−17.69	−2.02	0.02
(B) Casual visual botanical species richness				
Site use	−0.02	−0.06	0.01	0.23
Gender (male)	−0.71	−15.09	13.67	0.94
Age	−0.15	−0.79	0.50	0.65
Socio–economic status	−0.65	−9.43	8.14	0.89
Ethnicity–deprivation	−3.22	−12.68	6.25	0.51
Eco–centricity	−8.40	−15.98	−0.82	0.03

Vegetation characteristics explained much of the variation in perceived species richness (Nakagawa & Schielzeth's $R^2 = 0.61$). Perceived species richness increased with species evenness (using evenness measures from both complete and casual visual surveys although the former was only marginally significant), vegetation height and was higher in plots perceived to be more colourful (Table 5). We observed no relationships with forb to grass ratios, perceived naturalness, weediness or the percentage cover of flowers (Table 5).

4. Discussion

4.1. Does meadow creation increase perceptions of biodiversity?

Respondents did not perceive higher species richness, of plants or other taxonomic groups, at meadow creation sites compared to control sites. This finding occurs despite taking into account the amount of time respondents spent at the site and socio-demographic traits, such as age, which have previously been associated with interest in biodiversity (Lindemann-Matthies & Bose, 2008). Across individual meadow treatments perceived species richness did increase with actual species richness detected by an experienced botanist in complete surveys and more casual surveys conducted from the edge of the plots, which

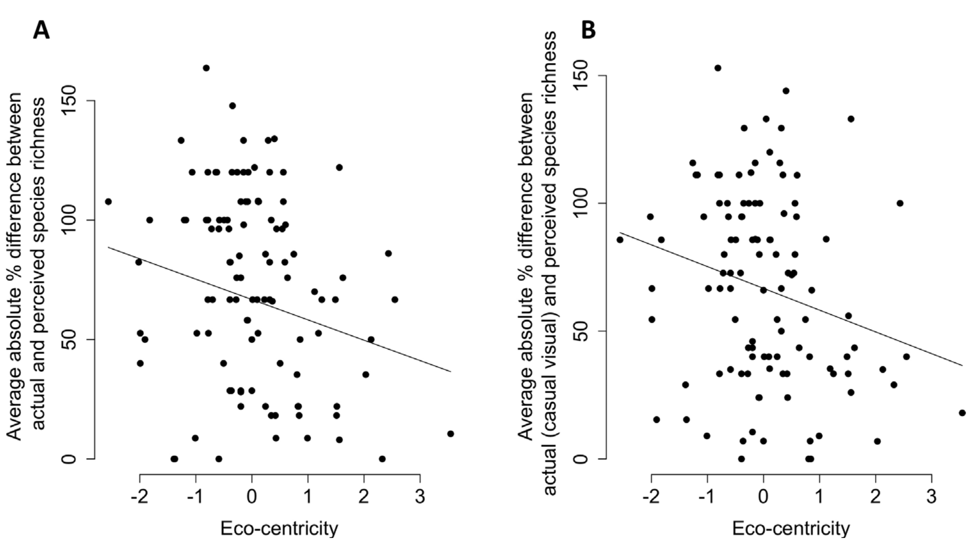

Fig. 1. Respondents with higher eco-centricity perceive plant species richness more accurately than those with lower eco-centricity when comparing perceived richness with actual richness in a) full botanical surveys and b) casual visual surveys that more closely mimic how respondents view the plots. Units on the X axes represent the magnitude of difference between full and casual surveys with 0 = no difference.

Table 5
Results of a linear mixed effect model of perceived plant species richness as a function of measured vegetation features that respondents might use as a cue to estimating species richness. Data reported are parameter estimates, their 95% confidence intervals and P values. Model $R^2 = 0.61$, which was estimated using a Pseudo R^2 approach as outlined by Nakagawa & Schielzeth (2013) and Johnson (2014).

Vegetation feature	Parameter estimate	Lower CI	Upper CI	P value
Casual Evenness	0.16	0.09	0.22	< 0.001
Actual Evenness	0.06	0.001	0.12	0.06
Casual Forb:grass ratio	0.002	−0.05	0.05	0.94
Actual Forb:grass ratio	0.006	−0.07	0.09	0.88
Flowering abundance	−0.01	−0.10	0.08	0.81
Vegetation height	0.07	0.02	0.11	0.002
Perceived colourfulness	0.12	0.05	0.18	0.001
Perceived naturalness	0.008	−0.05	0.06	0.77
Perceived weediness	−0.0002	−0.06	0.06	1.0

matched the respondents' views of the plots. Respondents could thus recognise that urban meadows contained more species than the treatment (short vegetation sown only with grass) that mimicked mown amenity grassland. The meadow treatments lack of impact on perceived site level species richness is perhaps partly a spatial scale issue, as meadows only occupied a small part of the site, on average 8%, but they were visually prominent and located in frequently visited parts of the sites. In addition, respondents may not have considered that the meadows added to the original biodiversity of the sites, as they all contained some semi-natural vegetation (mature trees, shrubs, and hedgerows). Finally, the contrast between site level and meadow plot results may reflect experiential differences promoted by the methods used in our two study phases. Respondents were invited to be more consciously involved when estimating species richness at the plot level than during the site level assessments, and other studies suggest that people are more likely to notice biodiversity when consciously asked to look for it (Shwartz, Turbe, Simon & Julliard, 2014).

4.2. Does meadow creation increase health and psychological well-being?

We found no evidence that meadow creation influenced mental and physical health, psychological well-being, or nature connectedness and site satisfaction which can moderate health and well-being outcomes. These findings could also be partly attributed to the spatial scale of the meadows. Ecological restoration projects can also create disturbances that reduce the physical and spatial stability of an individual's personal place attachment to the site (Brown and Perkins, 1992; Devine-Wright 2009). Initial perceptions can however change over time as familiarity and acceptance increases (Barro and Bright, 1998). We consider that respondents' health and well-being responses to the meadow treatments are, however, unlikely to change markedly over time as at the time of the survey there were no obvious signs of disturbance, and the meadows were similar in their appearance to that in subsequent years (Fig. S3).

4.3. Effects of perceived biodiversity and site use on health and psychological well-being

We found no evidence that health and well-being metrics were related to perceived species richness. This is unsurprising for physical health as this is likely to be driven by other factors such as exercise and recreational walking (Sugiyama, Leslie, Giles-Corti, & Owen, 2008; Barton & Pretty, 2010). Our results contrast with Dallimer et al. (2012) and Fuller et al. (2007) who found that respondents visiting urban green-spaces perceived to contain more species had higher psychological wellbeing. Our methodology was different, however, focusing on analyses at the respondent level rather than site level. This methodological difference may partly contribute to the difference in results as we found a positive correlation between continuity with the past and perceived richness at the site level ($r = 0.28$; $n = 8$), but other correlations were much weaker or negative (reflection $r = 0.11$; mental health $r = 0.08$; physical health $r = -0.40$; no correlation could be run for attachment as all sites had the same mean attachment values)

Perceived species richness was positively associated with site satisfaction and nature connectedness–factors that can moderate health and well-being outcomes (Capaldi et al., 2014; Zhang et al., 2015). Biodiverse sites may increase satisfaction as observing biodiversity can relate to an individual's overall sense of ecosystem health and balance and promote feelings of stability and continuity (Buijs, Fischer, Rink & Young, 2008; Fischer and Young, 2007). The positive association between perceiving biodiversity and feeling a greater connection to nature highlights the importance of encountering biodiverse environments. This is particularly important given that the relationship between urban dwellers and the nature they experience is in decline or homogenised (Soga et al., 2015; Pyle, 2003).

We found that people who used the site most (thereby receiving a higher dose of nature) reported feeling greater continuity with the past. Continuity of the self through time is considered to be an important psychological state that can be linked with enhanced positive self regard (Vess, Arndt, Routledge, Sedikides, & Wildschut, 2012) and confer meaning to one's life (Sedikides, Wildschut, Arndt, & Routledge, 2008). Additionally, the maintenance of a link with a particular place can promote a sense of continuity and purpose to an individual's identity, both past and present (Twigger-Ross & Uzzell, 1996). Moreover, people who used the site more frequently were more likely to have higher self-estimated mental health. This finding supports the growing body of literature pertaining to positive links between green-space and mental health (Mantler & Logan, 2012; Mitchell and Popham, 2008; van den Berg, van Poppel, van Kamp, & Maas, 2016) and further corroborates emerging research on the importance of nature dose exposure to health and well-being (Shanahan et al., 2016).

4.4. Factors influencing perceived biodiversity, and its accuracy

The significant positive relationship between perceived and actual species richness concur with observations of Fuller et al. (2007) and Qiu, Lindberg, and Nielsen (2013), who reported significant correlations between actual and perceived plant species richness in urban parks. In contrast, Dallimer et al. (2012) observed a negative correlation between perceived and actual plant species richness along river corridors. It is plausible that these differences arise because the cues used by people to estimate plant species richness have different correlations with actual plant species richness in different environments. One potential cue is the amount of vegetation, and meadow height was positively associated with perceived plant richness in our plots. Vegetation height may thus be a good predictor of botanical richness in grassland dominated environments, such as parks, but a poorer predictor in sites containing a mix of woodlands and grasslands (such as those in the Dallimer et al. (2012) study) as woodlands typically contain fewer plant species than grasslands despite containing more vegetation.

Whilst vegetation height was associated with perceived richness, evenness of the community composition had the strongest association with perceived species richness. This is an important finding as it suggests that rarer species are less likely to be detected and contribute to perceived species richness. Consequently if perceived species richness is an important driver of well-being benefits then locations that support similar numbers of common species but differ in the number of locally rare species may not vary in their well-being benefits. Finally, meadow plots that people perceived to be more colourful were also perceived to contain more species. However, the directionality of this relationship is unclear as studies have shown some evidence that the perception of vegetation colour was enhanced by increased species richness (Thorpert & Nielsen, 2014). More work in this area is required as colour may be a key factor influencing human perception of vegetation and species detectability (Kendal et al., 2013).

We find that respondents with higher eco-centricity (comprising ecological knowledge and pro-environmental behaviour) were significantly more accurate when estimating species richness. This finding extends the conclusion of Lindemann-Matthies and Bose (2008), who found that people with a professional background in biology were more accurate at estimating species richness than members of the public without such a background. We thus provide evidence that people with eco-centric traits are more likely to gain well-being benefits from perceiving species rich assemblages, providing additional incentives for improving environmental and ecological knowledge.

5. Conclusion

We find limited evidence that nature based solutions, creation of urban meadows, influenced visitors' perceived biodiversity at the site or their health and psychological well-being metrics. This may partly be a consequence of converting a small proportion of these sites' mown amenity grassland areas into urban meadows, as people could perceive increased species richness in the meadow plots themselves. Moreover, perceived species richness was positively associated with greater connection to nature and improved site satisfaction, two factors that can moderate health and well-being outcomes. These moderating factors contributing to psychological well-being were also influenced by the extent of a respondent's 'dose of nature', with higher outcomes demonstrated in those who used the sites most. People could accurately perceive differences in the number of plant species in different meadow communities, and appear to use a diversity of cues including the amount of vegetation, colourfulness and the evenness of the plant community to estimate species richness. Variation in the strength and direction of correlations between these cues and actual species richness may contribute to conflicting results in previous studies of people's ability to estimate plant species richness. Respondents with higher levels of eco-centricity could predict species richness more accurately, suggesting that they are more likely to gain benefits from species rich habitat creation than those less connected to nature. Overall, our findings indicate that managing urban green-spaces for biodiversity, for example through creation of urban meadows, could have positive health outcomes by influencing moderating factors. Delivering these benefits to a large number of people may, however, require improving biodiversity literacy.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.landurbplan.2017.12.002.

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