Psychological benefits of greenspace increase with biodiversity

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The world's human population is becoming concentrated into cities, giving rise to concerns that it is becoming increasingly isolated from nature. Urban public greenspaces form the arena of many people's daily contact with nature and such contact has measurable physical and psychological benefits. Here we show that these psychological benefits increase with the species richness of urban greenspaces. Moreover, we demonstrate that greenspace users can more or less accurately perceive species richness depending on the taxonomic group in question. These results indicate that successful management of urban greenspaces should emphasize biological complexity to enhance human well-being in addition to biodiversity conservation.

Keywords: urban greenspace; biodiversity; psychological well-being; Attention Restoration Theory

1. INTRODUCTION

Approximately half of the world's people live in urban areas (United Nations 2004). Rapid urbanization has increasingly isolated people from experiences of nature (Wilson 1984; Miller 2005). Indeed, for much of the population, remnant or managed public urban greenspaces provide one of the few avenues for direct contact with the natural environment. This is of profound concern, because such interaction leads to a variety of measurable benefits, at both individual and societal levels. In a now classic paper, Ulrich (1984) reported that post-surgical patients whose hospital windows overlooked trees, rather than a brick wall, recovered more rapidly and required less pain relief. Subsequent research revealed that a range of human well-being measures responds positively to greenspace availability, including general health (de Vries *et al.* 2003), degree of social interaction (Sullivan *et al.* 2004) and mental fatigue (Kuo 2001), and opportunities for reflection (Herzog *et al.* 1997).

While the effects of 'green' environments are increasingly well understood, little is known about the importance of variation in the quality of greenspace

for benefits to human well-being. Here, we show that the psychological benefits gained by greenspace users increase with levels of species richness, and moreover those visitors to urban greenspaces can perceive differences in the species richness of some well-known higher taxa.

2. MATERIAL AND METHODS

(a) *Study areas*

Research was conducted in Sheffield, a city of 513 000 people (Office for National Statistics 2001). All greenspaces more than one hectare with public access were selected along a wedge-shaped transect from the city centre to the western suburbs. The area (13 km²) incorporated a range of residential urban forms from high-density city centre developments to low-density suburbs, and yielded 15 greenspaces.

(b) *Species richness*

During summer 2005, plant communities were sampled with quadrats in each greenspace. Using Ordnance Survey (2006) MASTERMAP data and field surveys, land parcels were classified into seven habitat types (amenity planting, mown grassland, unmown grassland, scrub, woodland, water and impervious surface) and 20 quadrats of 1 m² were randomly located within the area occupied by each type. All species of herbaceous plants were identified within each quadrat. Woody species (mainly large shrubs and trees) were sampled with 10×10 m quadrats placed using a similar protocol. Where the shape of a habitat parcel did not allow placement of a quadrat, the quadrat's shape was modified to fit, keeping area constant. Quadrats were placed until 20 were located or all habitat was sampled. Species richness estimates (species density of Gotelli & Colwell 2001) were calculated using the second-order jackknife estimator computed over 1000 runs in the ESTIMATES software (Colwell 2005). Total plant richness is the $\log_{10}$-transformed sum of estimates for woody and herbaceous plants.

Butterflies were surveyed using standard UK Butterfly Monitoring Scheme methodology (Pollard *et al.* 1986). A transect was established across each greenspace, covering each habitat type (excluding water) approximately in proportion to its extent. Transects varied from 925 to 2015 m in length depending on greenspace size. All butterflies less than 2.5 m on either side of the route and less than 5 m in front of the observer were recorded. Transects were walked five times in suitable weather, every two weeks between June and August 2005. Species richness was the total number of species recorded across all surveys.

While conducting butterfly surveys, bird species heard or seen within the greenspace boundary were noted (excluding overflying birds not actively feeding or hunting). All habitats were surveyed over approximately 2 h in each greenspace. The intention was to list the species most likely to be encountered during a typical summer visit. Resultant species accumulation curves for the bird and butterfly data showed clear signs of attaining an asymptote, indicating detection of a large proportion of species.

(c) *Psychological well-being and perceived species richness*

Semi-structured interviews were conducted *in situ* with 312 greenspace users (July–October 2005). Closed-ended questions explored psychological well-being and respondents' perceptions of greenspace species richness. Well-being measures focused on greenspace as a source of cognitive restoration, positive emotional bonds and sense of identity. Responses were made on a five-point Likert scale from strongly disagree to strongly agree based on the stem question 'Please indicate how much you agree with each statement about this park' (electronic supplementary material). Five statements measured likelihood of recovery from mental fatigue and the opportunity for reflection, derived from attention restoration theory (Kaplan & Kaplan 1989). Eighteen statements explored emotional attachment to, and personal identity gained from, the greenspace drawn from theory and research on place (e.g. Manzo 2003; Patterson & Williams 2005; electronic supplementary material).

Factor analysis (electronic supplementary material) identified groups of statements measuring a single component of psychological well-being. Components were interpretable as *reflection* (ability to think and gain perspective); *distinct identity* (degree of feeling unique or different through association with a particular place); *continuity with past* (extent to which sense of identity is linked to greenspace through continuity across time); and *attachment* (degree of emotional ties with the greenspace). All four components had clear roots in the theoretical frameworks mentioned above. Continuous measures were derived by calculating each participant's average rating of the set of statements forming each component.

Table 1. Greenspace characteristics, psychological well-being and perceptions of species richness in urban greenspaces. See text for details of measures. Perceived species richness is the mean of the scale values of the richness categories (1–4; see footnotes). For further details and location of sites A–O, see electronic supplementary material.

site	area (Ha)	woody plant richness (s.d.)	herbaceous plant richness (s.d.)	butterfly species richness	bird species richness	reflection (s.d.)[a]	distinct identity (s.d.)[a]	continuity with past (s.d.)[a]	attachment (s.d.)[a]	perceived plant richness[b]	perceived butterfly richness[c]	perceived bird richness[d]
A	23.76	64.7 (6.4)	96.6 (8.8)	6	12	4 (0.61)	3.67 (0.77)	3.41 (1.05)	4.40 (0.44)	2.61	1.89	2.82
B	16.02	111.4 (11.8)	143.4 (9.69)	14	18	3.97 (0.79)	3.94 (0.66)	3.66 (0.73)	4.50 (0.61)	2.17	1.61	1.85
C	6.94	328.9 (20.6)	274.2 (19.5)	8	8	4.14 (0.66)	4.30 (0.42)	3.38 (0.83)	4.71 (0.36)	3.55	1.95	2.12
D	2.27	41.6 (6.1)	67.3 (6.8)	10	17	3.29 (1.35)	3.13 (1.13)	3.23 (0.74)	4.46 (0.78)	2	1.8	2.33
E	5.66	102.6 (9.2)	93.7 (8.4)	6	7	3.93 (0.57)	3.27 (1.01)	3.27 (0.88)	4.26 (0.66)	2.37	1.65	1.95
F	1.22	29 (10)	75.1 (8.8)	5	4	3.08 (0.59)	2.85 (0.81)	2.50 (0.96)	3.85 (0.67)	1.36	1.09	1.2
G	1.4	47.8 (5.9)	39.8 (5.1)	5	8	3.72 (0.73)	3.44 (0.70)	2.94 (0.94)	4.45 (0.62)	2	1.60	2.05
H	15.05	75.7 (8.9)	159 (17.4)	7	22	3.83 (0.73)	4.03 (0.57)	3.40 (0.68)	4.61 (0.47)	2.69	1.82	2.2
I	3.12	78.6 (10.7)	95.6 (7.6)	9	7	3.7 (1.11)	2.99 (0.85)	3.01 (1.29)	4.10 (0.87)	2	1.53	1.84
J	3.81	19 (4.2)	82.6 (9)	5	4	3.46 (0.67)	3.33 (0.7)	3.24 (0.72)	4.24 (0.54)	1.8	1.18	1.67
K	7.55	37.9 (7.2)	51 (6.8)	10	11	4.06 (0.59)	4.09 (0.57)	3.53 (0.96)	4.62 (0.41)	1.89	1.4	1.9
L	12.9	70.8 (7.6)	80.9 (9.5)	9	11	3.79 (1.01)	3.37 (0.7)	3.02 (0.87)	4.25 (0.97)	1.67	1.63	1.83
M	4.01	68.5 (6.7)	74.7 (8)	12	13	3.67 (0.86)	3.10 (0.71)	3.03 (1.02)	4.29 (0.56)	1.85	1.5	1.67
N	5.57	74.9 (8.7)	196.4 (13.9)	11	16	4 (0.85)	3.69 (0.52)	3.18 (0.84)	4.43 (0.60)	2.9	1.95	2.42
O	4.90	127.1 (10.6)	98.5 (9.2)	7	7	3.69 (0.69)	3.36 (0.53)	2.59 (0.77)	4.22 (0.67)	2.37	1.62	2

[a] 1–5 scale: 1 = strongly disagree to 5 = strongly agree.
[b] 1–4 scale: 1 = less than 10 types, 2 = 10–100 types, 3 = 100–300 types, 4 = more than 300 types.
[c] 1–4 scale: 1 = less than 4 types, 2 = 4–10 types, 3 = 10–20 types, 4 = more than 20 different types.
[d] 1–4 scale: 1 = less than 5 types, 2 = 5–14 types, 3 = 15–30 types, 4 = more than 30 different types.

Table 2. Linear regressions exploring relationships between biodiversity value (habitat heterogeneity, tree cover and species richness), area and psychological well-being. Each pairwise combination of variables was tested separately and the resulting model, where significant, is shown. Then, area was entered into each significant model as a second term and backward stepwise selection was used to eliminate any term satisfying the removal criterion ($p > 0.05$) with the smaller partial R^2 at each stage. In two cases, shown in bold, the biodiversity measure was eliminated from the multivariate model, indicating that the effect of area was stronger than that of the biodiversity measure. In all other cases, the area term was excluded. $b =$ model coefficient. In all cases, model significance $0.01 < p < 0.05$.

	reflection	distinct identity	continuity with past	attachment
no. of habitats	$b = 0.131$ $F = 16.03$ $R^2 = 0.552$	$b = 0.139$ $F = 5.267$ $R^2 = 0.288$	$\boldsymbol{b = 0.099}$ $\boldsymbol{F = 4.697}$ $\boldsymbol{R^2 = 0.265}$	
tree cover				
plant richness	$b = 0.747$ $F = 6.336$ $R^2 = 0.328$	$b = 1.012$ $F = 5.034$ $R^2 = 0.279$		
butterfly richness				
bird richness			$\boldsymbol{b = 0.033}$ $\boldsymbol{F = 5.538}$ $\boldsymbol{R^2 = 0.299}$	$b = 0.024$ $F = 6.278$ $R^2 = 0.341$
greenspace area	$b = 0.024$ $F = 5.163$ $R^2 = 0.284$	$b = 0.035$ $F = 4.842$ $R^2 = 0.271$	$b = 0.028$ $F = 6.096$ $R^2 = 0.319$	

To assess perceptions of species richness, we asked 'About how many different types of plants/butterflies/birds would you say are in this park?' Continuous measures were calculated based on a four-point scale appropriate to each taxon (electronic supplementary material).

3. RESULTS

Total plant richness varied by an order of magnitude among the 15 greenspaces, while butterfly and bird richness varied three- and fivefold, respectively (table 1). Given the theoretical basis for positive species–area relationships, the effect of area as a predictor of the well-being measures was considered in all analyses. While we recognize that care is needed when interpreting results of multiple comparisons, we did not apply a correction, as our contrasts were planned and we are studying a complex response (Moran 2003). Park area was positively correlated with the number of habitat types ($r = 0.65$, $n = 15$, $p = 0.009$), but unrelated to plant richness ($r = 0.29$, $n = 15$, $p = 0.296$). The number of habitat types was positively correlated with plant richness ($r = 0.7$, $n = 15$, $p = 0.003$).

Psychological well-being measures also varied across greenspaces (table 1). *reflection*, *distinct identity* and *continuity with past* increased with greenspace area (table 2). Plant richness was positively associated with *reflection* and *distinct identity* (figure 1a,b), both effects stronger than those of area (table 2). Butterfly richness was not associated with any well-being measure (table 2). Bird richness was positively related to *continuity with past* and *attachment*, although the former effect was weaker than that of area (table 2). The number of habitat types was positively associated with *reflection*, *distinct identity* and *continuity with past* (figure 1c; table 2), although tree cover was unrelated to any well-being measure (table 2).

Perceived plant richness increased strongly with sampled plant richness ($r = 0.84$, $n = 15$, $p < 0.001$; figure 2a). No apparent relationship existed between perceived and measured butterfly richness ($r = 0.25$,
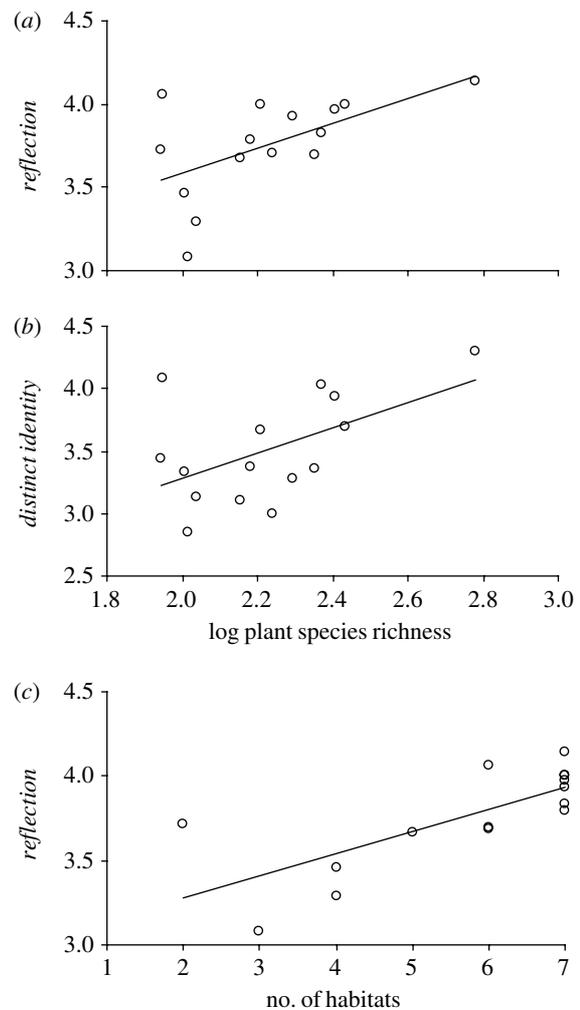
Figure 1. Relationship between log plant species richness and (a) *reflection*, (b) *distinct identity* and (c) the relationship between number of habitat types present in a greenspace and *reflection*. See text and table 1 for explanation of units.

$p = 0.366$; figure 2b), although for birds there was a marginally non-significant positive relationship
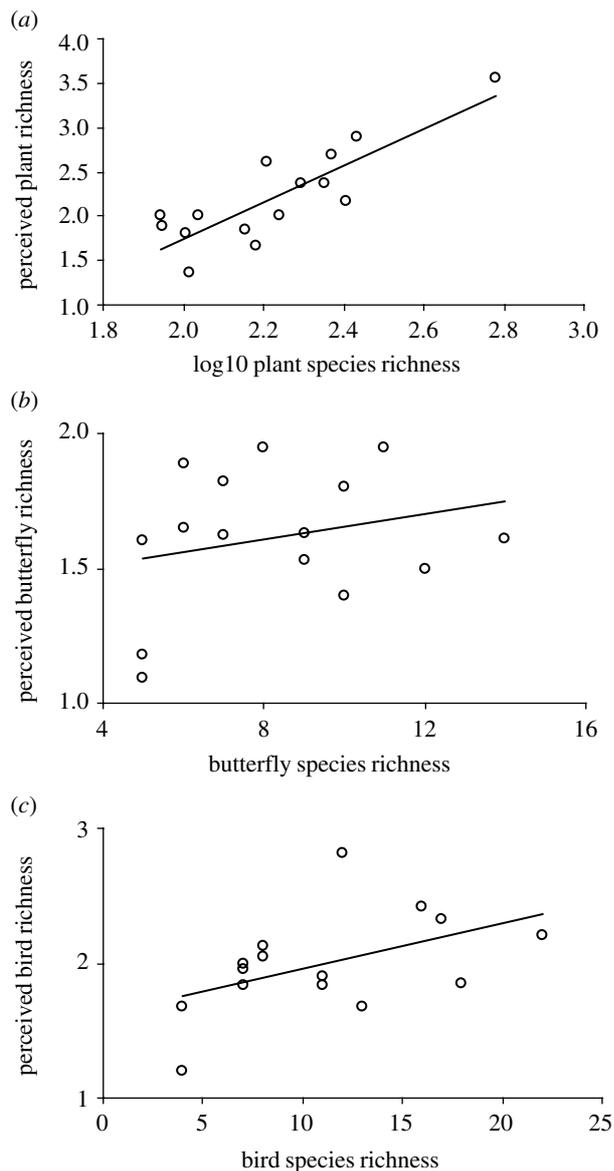
Figure 2. Relationship between perceived and sampled species richness of (*a*) plants, (*b*) butterflies and (*c*) birds. The relationship in the plant data remains highly significant on removal of right-hand data point. See text and table 1 for explanation of units.

($r = 0.49$, $p = 0.066$; figure 2*c*). Perceived plant richness was positively correlated with the number of habitats ($r = 0.58$, $n = 15$, $p = 0.023$).

4. DISCUSSION

Our data demonstrate measurable positive associations between the species richness of urban greenspaces in Sheffield and the well-being of greenspace visitors. The degree of psychological benefit was positively related to species richness of plants and to a lesser extent of birds, both taxa where perceived richness corresponded with sampled richness. While benefits did increase with greenspace area, the relationships with plant and bird richness were generally stronger. Our species richness measures encompass effects of taxon density and heterogeneity, and we do not distinguish the two effects here. The number of different habitats was correlated with reflection and personal identity, plant variety with

the ability to reflect and bird variety with participants' emotional attachment.

Our results indicate that the respondents, surrounded by urban built form, are not completely disconnected from an experience of biodiversity, but that their ability to perceive ambient species richness varies across taxonomic groups. People assessed most accurately the visible static components of biodiversity namely, plant species richness. Perceptions of bird and butterfly richness, arguably more cryptic components of urban ecosystems in terms of behaviour and ease of species differentiation, respectively, were less accurate.

Although these associations emerge quite clearly, untangling causality is not easy. First, it is unlikely that people were randomly distributed among parks, perhaps preferring those that enhance their psychological well-being. Selection by individuals of environments that enhance personal well-being makes interpretation of the causal structure of these relationships difficult, but is an important effect in its own right. Increased well-being may result from a variety of different kinds of greenspace, allowing individuals to access greenspaces from which they benefit most. Second, the increase in psychological well-being with species richness and the accurate assessment of richness levels presumably operate through some proxy mechanism. Positive relationships between the number of habitats in the greenspace and (i) psychological benefits gained by users and (ii) perceived levels of plant diversity hint that gross structural habitat heterogeneity might cue the perceptions and benefits of biodiversity. If this is the case, management emphasizing a mosaic of habitat patches (Thwaites *et al.* 2005) may enhance biodiversity levels, ecosystem service provision and the well-being of the human urban population.

Our results indicate that simply providing greenspace overlooks the fact that greenspaces can vary dramatically in their contribution to human health and biodiversity provision. Consideration of the quality of that space can ensure that it serves the multiple purposes of enhancing biodiversity, providing ecosystem services (Arnold & Gibbons 1996), creating opportunities for contact with nature (Miller 2005) and enhancing psychological well-being. Given the cultural differences in perceptions of wildlife (Jim & Chen 2006), an interesting extension of our study could test the generality of our results in other cultural settings.

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