Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness

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Over half of the world's human population lives in cities, and for many, urban greenspaces are the only places where they encounter biodiversity. This is of particular concern because there is growing evidence that human well-being is enhanced by exposure to nature. However, the specific qualities of greenspaces that offer the greatest benefits remain poorly understood. One possibility is that humans respond positively to increased levels of biodiversity. Here, we demonstrate the lack of a consistent relationship between actual plant, butterfly, and bird species richness and the psychological well-being of urban greenspace visitors. Instead, well-being shows a positive relationship with the richness that the greenspace users perceived to be present. One plausible explanation for this discrepancy, which we investigate, is that people generally have poor biodiversity-identification skills. The apparent importance of perceived species richness and the mismatch between reality and perception pose a serious challenge for aligning conservation and human well-being agendas.

Keywords: ecosystem services, human–wildlife interactions, psychological well-being, urban greenspace, urban ecology

Urbanization results in some of the most profound changes to the natural world of any human-driven land conversion (Marzluff and Ewing 2001). Towns and cities are now home to over half the world's human population (United Nations 2008), and with urbanization increasing, there is a growing concern about the effects both on biodiversity (Chace and Walsh 2006, McKinney 2008) and on people (Dye 2008). Indeed, as more people's lives are dominated by urban experiences, the gap between humans and the natural world may become ever greater (Miller 2005). However, evidence has been accumulating of the personal and societal benefits that derive from exposure to natural environments (Irvine and Warber 2002, Brown and Grant 2005). For instance, increases in the amount of greenspace in a neighborhood are associated with improvements in longevity (Takano et al. 2002) and self-reported health (de Vries et al. 2003, Maas et al. 2006) in addition to reduced mortality from circulatory diseases (Mitchell and Popham 2008). People who visit urban parks report fewer visits to physicians (Godbey et al. 1998), whereas those who engage in exercise in the presence of nature report better improvements in mood and self-esteem than those who exercise in nonnatural surroundings (Barton and Pretty 2010). Exposure to natural environments is also associated with quicker recovery rates from surgery (Ulrich 1984), increased social interaction (Sullivan et al. 2004), improved cognitive functioning (Berman et al. 2008), reduced mental fatigue (Kuo 2001), lower crime rates (Kuo and Sullivan 2001), and the provision of opportunities for reflection (Fuller et al. 2007) and stress amelioration (Ulrich et al. 1991, Parsons et al. 1998, Yamaguchi et al. 2006).

The particular reasons that nature has advantageous properties for human health and well-being remain unclear, not least because the relationships between people and the natural environment are likely to be extremely complex. Indeed, people from all backgrounds value biodiversity for a broad range of reasons (MA 2005), and the benefits of urban nature are experienced by a wide variety of people in a range of different greenspaces, including domestic gardens, urban parks, and seminatural habitat patches (Irvine et al. 2010). However, there has been little study of the direct effects of or mechanisms behind the impacts of specific biological components of greenspaces on human quality of life (Brown and Grant 2005). To date, in research on the benefits to health and psychological well-being that humans gain from urban nature, the natural environment has generally been

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treated as uniform, often characterized simply as the amount or proximity of greenspace. This approach largely ignores the biological components that are typically measured in urban ecology, such as species richness. There is emerging evidence that in doing so, one not only ignores the complexity of urban habitats but also masks the potentially important responses of people to specific components of natural environments. One intriguing possibility, supported by a number of strands of evidence, is that people have a positive response to increased levels of biodiversity. For instance, in Denmark, nearly half of the respondents to a survey indicated that flora and fauna were among their motivations for visiting greenspaces (Schipperijn et al. 2010). Being in the natural environment and seeing local wildlife were two main reasons that urban residents in five English cities visited local greenspaces, and around two-thirds of the respondents in a study of Sheffield greenspace users said that the diversity of flora and fauna was valuable (Irvine et al. 2010). Where specific components of biodiversity have been explicitly studied, it has been found that psychological well-being is enhanced in publicly accessible and managed urban greenspaces (e.g., amenity parks) containing more plant species (Fuller et al. 2007), and people demonstrate a greater aesthetic appreciation for more-diverse plant communities (Lindemann-Matthies et al. 2010).

Urban greenspaces therefore offer city residents opportunities for improving both their physical health and their psychological well-being, the latter potentially through the development of positive emotional bonds, a sense of identity, and facilitating reflection and recovery from mental fatigue (Proshansky et al. 1983, Kaplan and Kaplan 1989, Altman and Low 1992). We wished both to investigate the potential covariation between psychological well-being and species richness and to test mechanisms that could underpin any such associations. We did this using an urban riparian greenspace study system that encompasses a marked variation in biodiversity (e.g., from 22 plant species in depauperate areas to 95 species in diverse sites), a range of habitats (woodland, brownfield sites, open locations), and levels of management (formal planting to seminatural habitats). We explicitly tested the hypothesis that psychological well-being will show a positive correlation with actual species richness. In addition, we examined whether greenspace users can accurately estimate the biodiversity associated with a site by comparing actual species-richness data estimated from ecological surveys with perceived species richness. Wildlife identification skills, commonly acknowledged as being weak in the developed world (Bebbington 2005, Pilgrim et al. 2008), were also assessed as one mechanism by which biodiversity levels might be predicted.

In the United Kingdom, around 90% of the population inhabits urban areas. There is, therefore, an urgent need to understand the benefits that may be derived from urban greenspace within such an intensely human-dominated region. We used Sheffield, the fifth-largest city in England, with a human population of 520,700, as our study system. Since Sheffield lies at the confluence of five rivers, riparian areas offer an important recreational resource for the city's residents, especially since they are distributed throughout the urban, suburban, and more rural periphery. Thirty-four sites with public access were selected to represent the range of riparian greenspaces available to city dwellers; they spanned a wide geographic area across all of the city's rivers (figure 1), and many of them were publicly owned or managed and seminatural in character (see also supplemental figure S1, available online at *http://dx.doi.org/10.1525/bio.2012.62.1.9*).

Biodiversity surveys

Bird, butterfly, and plant species richness were surveyed at each site. Using standard protocols, bird surveys were carried out on two separate occasions at each site between 29 March and 26 June 2009, with the second at least six weeks after the first. To ensure that the maximum number of species was encountered, the visits began between one and three hours after sunrise, when a five-minute point count was performed, and the identity of each bird was noted. A list of all species recorded at each site during both surveys was compiled. Centered on the avian point-count location, and running parallel to the riverbank, a 40 × 10 meter (m) area was actively searched for butterflies for a fixed time period of 15 minutes. The sites were visited three times (in late May or early June, in July, and in August), and a list of

Figure 1. The urban area of Sheffield, United Kingdom, (shaded) showing the major rivers running through the city (solid lines) and study sites (filled circles). The inset shows the location of Sheffield in Britain.

all encountered species was compiled. The botanical flora (all forbs and woody plants) in the same 40 × 10 m area was exhaustively surveyed.

The species richness of plants and birds varied more than fourfold across the 34 sites, whereas butterfly richness ranged from zero to nine species (table 1). There were no correlations of species richness among the taxonomic groups (Spearman's rank correlation between butterflies and birds, $r_s = .245$, $p = .167$; between plants and birds, $r_s = -.195$, $p = .277$; between plants and butterflies, $r_s = .261$, $p = .150$). The data were not normally distributed, which precluded the use of parametric correlation tests.

Table 1. For 34 riparian greenspaces, site-level median and range for ecological characteristics, the number of participants, the psychological well-being of visitors, their perception of species richness, and their level of wildlife knowledge.

Variable	Median	Range
Bird species richness (number of species)	12	4–18
Butterfly species richness (number of species)	2	0–9
Plant species richness (number of species)	43	22–95
Habitat diversity (Shannon diversity index)	1.16	0–1.84
Tree cover (proportion of the 50-meter-radius study area)	.37	.05–.91
Number of participants	34	10–46
Psychological well-being[†]		
Reflection	3.99	3.26–4.43
Attachment	4.32	3.42–4.67
Continuity with the past	3.26	2.40–3.86
Perceived species richness[†]		
Birds	2.69	1.88–3.52
Butterflies	3.13	2.70–3.80
Plants	3.13	2.34–3.90
Wildlife knowledge		
Birds	1.38	0.50–2.17
Butterflies	0.29	0.07–0.79
Plants	0.32	0.11–0.60
Total number of species identified	2.09	0.78–3.17

Note: The wildlife knowledge scores are the median number of correctly identified images (up to a maximum of 4 per taxon and 12 in total).
[†]These scores were based on a five-point scale. For all three measures of psychological well-being, a score of 1 corresponded to *strongly disagree* with the questionnaire statement, a score of 5 to *strongly agree*. For the perceived species richness of birds, 1 corresponded to *fewer than 5 species*, 2 to *between 5 and 9 species*, 3 to *between 10 and 13 species*, 4 to *between 14 and 19 species*, and 5 to *20 or more species*. For the perceived species richness of butterflies, 1 corresponded to *none*, 2 to *1 species*, 3 to *between 2 and 4 species*, 4 to *between 5 and 9 species*, and 5 to *10 or more species*. For the perceived species richness of plants, 1 corresponded to *fewer than 10 species*, 2 to *between 11 and 30 species*, 3 to *between 31 and 50 species*, 4 to *between 51 and 100 species*, and 5 to *more than 100 species*.

Of the plant species, 168 (63%) were native, 24 (9%) were archaeophytes and, two (1%) were of uncertain origin. The remaining 72 species (27%) were neophytes—that is, they were known to have been introduced to Britain after 1500 (Preston et al. 2002). The most frequently encountered plant species were bramble (*Rubus fruticosus*), dandelion (*Taraxacum* agg.), and sycamore (*Acer pseudoplatanus*). The most ubiquitous species of bird were the wren (*Troglodytes troglodytes*), the blackbird (*Turdus merula*), and the wood-pigeon (*Columba palumbus*). Charismatic species for the United Kingdom, such as the kingfisher (*Alcedo atthis*), the dipper (*Cinclus cinclus*), and the gray heron (*Ardea cinerea*), were also regularly recorded. Only two nonnative species were encountered (the feral pigeon [*Columba livia*] and the pheasant [*Phasianus colchicus*]). Whites (*Pieris*) were the most widespread butterfly species, followed by the speckled wood (*Pararge aegeria*). A full species list is given in supplemental appendix S1.

Urban river corridors show a high degree of environmental variation, which can affect species richness (Chace and Walsh 2006, McKinney 2008) and may influence the well-being of recreational greenspace users. We therefore measured two further environmental components of each site that were likely to be associated with species richness and also to be visible to recreational users of the river corridors. First, the habitat diversity at each site was calculated using the Shannon diversity index based on the percentage cover of broad habitat types recorded in the field across the same 40 × 10 m search area that was surveyed for butterflies and plants. Second, tree cover was mapped in a geographical information system by manually tracing around each tree or group of trees shown in aerial photographs (Davies et al. 2008). The proportion of cover in a 50-m-radius area around each site was then determined. We used generalized linear models with Poisson errors (corrected for overdispersion where necessary) to describe the relationships among species richness, tree cover, and habitat diversity. In the regression models, ecological characteristics explained some of the variation: There was a strong positive association between bird species richness and the habitat diversity of each site ($\beta = .32$, standard error [SE] = 0.08), but bird species richness was not related to tree cover, whereas plant species richness was lower at sites with a high proportion of tree cover in a 50-m radius of the survey location ($\beta = -.73$, SE = 0.27). Butterfly species richness was not related to either environmental variable.

Psychological well-being gain from urban greenspaces

We developed a questionnaire grounded in two theoretical frameworks in order to derive estimates of self-reported gains to psychological well-being for individual recreational visitors to each site (supplemental appendix S2). First, attention restoration theory proposes that the natural world is cognitively restorative and both facilitates recovery from mental fatigue and offers opportunities for reflection

(Kaplan and Kaplan 1989). Second, the sense-of-place framework suggests that the relationship between people and greenspaces may be understood in terms of the place itself, and the framework is focused on the emotional attachments and bonds that people have with physical locations (for an overview, see, e.g., Altman and Low 1992) and on the sense of identity that may be developed through association with a place (see, e.g., Proschansky et al. 1983). The questionnaire was delivered face-to-face *in situ* during September and October 2009 by five trained interviewers. In addition to closed-ended questions exploring psychological well-being, we also asked questions pertaining to perceptions of species richness and testing the ability to identify common riparian wildlife. Background data such as age, household income, gender, and ethnicity were also collected. We wished to engage with as wide a range of people using the riparian zones as possible. Therefore, each site was visited at least four times, covering daytime and early evening during weekends and weekdays; as a rule of thumb, every third person was approached. Over half (54.3%) of those asked to participate did so, which yielded 1108 completed questionnaires (with a median of 34 per site). Low use at two sites and access restrictions put in place during the questionnaire period at two others meant that fewer than 25 questionnaires were completed at these locations. Nevertheless, at these sites, the number of people interviewed represented over half of those using the stretch of river during the interview period, so they were not excluded from the analyses. The greenspace users were predominantly of European ethnicity (91.7%; broadly in line with the population of Sheffield as a whole, which is 91.2% of European descent), represented both genders well (62% male), and covered broad ranges of age (16 to more than 70 years) and household income (from below £10,000 to above £70,000 per year).

The measures of well-being were framed around the premise that the natural environment may facilitate cognitive restoration and reflection, emotional attachments, and identity. Seven statements were included to measure reflection and contemplation. A four-item reflection scale used in previous research (Fuller et al. 2007) was extended with three additional items that were developed for this study; all seven items were grounded in attention restoration theory (Kaplan and Kaplan 1989), literature on spiritual well-being (Hawks et al. 1995, Hood Morris 1996), and expanded health models (Engel 1977, McKee and Chappel 1992). A further 14 statements were used to explore emotional attachment and personal identity. These statements were modifications of those in Fuller and colleagues' (2007) work and were grounded in theory and research on the sense of place (e.g., Proshansky et al. 1983, Altman and Low 1992, Twigger-Ross and Uzzell 1996, Manzo 2003, Patterson and Williams 2005).

For all 21 well-being items, we used a five-point Likert scale (1, *strongly disagree*; 3, *neutral*; 5, *strongly agree*) in response to the stem prompt "Please indicate how much you agree with each statement about this stretch of river and the neighboring banks." The interviewers defined *stretch of river* to mean the immediate area of the river and riverbanks where the interview was taking place, which matched the biodiversity survey plot.

Given the lack of available standardized measures of gains to psychological well-being from greenspaces, we conducted factor analyses (see DeVellis 2003 for an overview of factor analysis as compared with the analogous principle components analysis) to identify meaningful groups of statements that could be used to measure a single aspect of self-reported well-being (Tabachnick and Fidell 2001). These were interpretable as *reflection* (the ability to think and gain perspective), *attachment* (the degree of emotional ties with the stretch of river), and *continuity with the past* (the extent to which the sense of identity is linked to the stretch of river through continuity across time) (supplemental appendix S2). Continuous measures were derived by calculating the participants' average ratings of the set of statements forming each factor. The psychological well-being measures differed across sites (table 1) and were correlated (reflection and continuity with the past, $r_s = .694$, $p < .001$; reflection and attachment, $r_s = .699$, $p < .001$; attachment and continuity with the past, $r_s = .604$, $p < .001$).

Perception of biodiversity

To understand whether visitors were able to perceive the amount of biodiversity that was around them, we asked the participants to estimate the number of different types of birds, butterflies, and plants at the study location (Fuller et al. 2007). This estimate could then be compared with the ecological survey data. On the basis of the actual variation in species richness present across all sites, a five-point scale was constructed that was specific to each individual taxonomic group (table 1). The lowest value on a scale corresponded to fewer species than were found to be present as part of the ecological surveys even on the most depauperate site, whereas the highest value signaled that the participants perceived there to be more species present at that locality than were actually observed on the most species-rich site. The intermediate values were defined as the quartiles for the distribution of actual richness that was estimated from the ecological surveys for that taxon. Site-level mean perceived richness scores were then calculated. Possible values could therefore range from 1 (all respondents choosing the lowest category) to 5 (all respondents choosing the highest category). The resulting site-level measures varied among the sites. In contrast to the actual species richness data, the perceived richness measures were correlated (butterflies and birds, $r_s = .526$, $p < .001$; plants and birds, $r_s = .411$, $p < .001$; plants and butterflies, $r_s = .354$, $p < .001$), perhaps indicating that the users of the sites responded to the same cues for assessing each taxa; indeed, perceived richness was positively correlated with tree cover (birds, $r_s = .604$, $p < .001$; butterflies, $r_s = .400$, $p = .019$; plants, $r_s = .410$, $p = .016$). The participants may have perceived a given level of richness for one taxonomic group and generalized to estimate the other two.

Contrary to our expectations and the available literature (e.g., Fuller et al. 2007, Lindemann-Matties et al. 2010), there was no association between perceived and actual species richness for any of the three taxonomic groups (figure 2). We hypothesized that this may be because the participants perceived there to be more species present when the amount of tree cover was higher, which, when combined with the negative relationships between—for example—actual plant species richness and tree cover, could drive the lack of association between perceived and actual richness. As was noted above, for all taxonomic groups, there was a positive correlation between perceived richness and tree cover. However, when we controlled for this association using partial correlations, there remained no significant association between perceived and actual richness across all three groups (birds, r_s = .299, p = .085; butterflies, r_s = .231, p = .193; plants, r_s = .051, p = .780).

Relationships between biodiversity and well-being

Across all of the taxonomic groups, well-being was positively related to the participants' perceived species richness of birds, butterflies, and plants (table 2). In contrast, when we quantified the relationship between actual species richness and all three measures of psychological well-being using linear regressions (table 2), we found that there were no consistent patterns. Although well-being increased with higher levels of bird species richness—a result that we anticipated on the basis of previous research (Fuller et al. 2007)—well-being actually declined with greater plant diversity, and there was no pattern with butterfly species richness (table 2).

It may be that greenspace users were responding to other environmental cues rather than directly to species richness, which suggests that there may be different, perhaps more relevant, aspects of biodiversity to measure if we wish to understand people's responses to the natural world. For example, in a future study, the role of charismatic species and their link to self-reported well-being might be explored. It is equally possible that the abundance of a given taxonomic group is more important or noticeable than the number of different species. We did not gather information on perceived abundances, and our questionnaire was specifically designed around species richness as a metric of biodiversity. However, during the biodiversity surveys, we did collect abundance data for birds using distance-sampling protocols to control for differences in detectability, although we do not have comparable data for butterflies or plants. All three measures of well-being were positively related with the total (cross-species) bird density (birds per hectare) at each site (reflection, β = .022, r^2 = .21; attachment, β = .026, r^2 = .24; continuity with the past, β = .028, r^2 = .22). However, in each case, the proportion of the variation in well-being explained by bird density was higher than that for the actual but lower than that for the perceived species richness (table 2).

Urban areas often contain a high proportion of nonnative species (Chace and Walsh 2006, McKinney 2008), and it is conceivable that people may respond more positively to native rather than to introduced biodiversity. However, in the riparian zones of Sheffield, greenspaces tend to be publicly owned or managed, seminatural in character, and not dominated by domestic plant varieties or formal planting. For example, only 28% of the plant species were neophytes within our study system, compared with over 70% of the flora in domestic gardens more generally (Loram et al. 2008). Furthermore, only 1 of the top 20 most widespread species was a neophyte (the sycamore—a tree common throughout the city). It is therefore unlikely that self-reported well-being is unduly influenced by the presence of large numbers of nonnative species. Indeed, whether a species is native or not only plays a minor role in determining whether the general public would like to see populations of that species increase (Fischer et al. 2011).

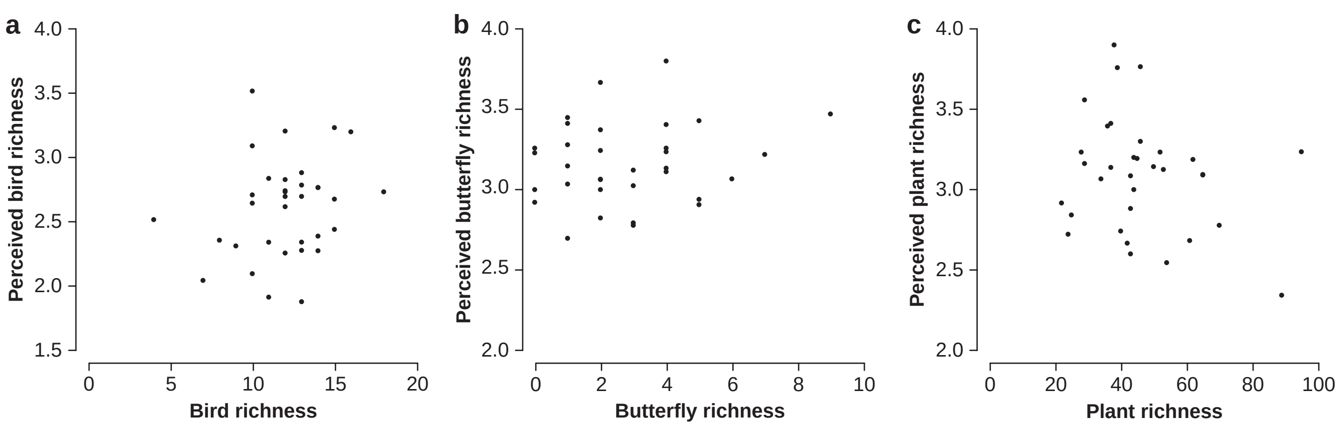

Figure 2. Association between mean site-level perceived and actual species richness for (a) birds (Spearman's rank correlation, r_s = .220, p = .211), (b) butterflies (r_s = .103, p = .570), and (c) plants (r_s = .135, p = .452). Each point represents a single site. The perceived richness is the median score on a five-point scale (see table 1 for a detailed explanation of the scoring).

Table 2. Linear regressions exploring the bivariate relationships between psychological well-being and surveyed (actual) species richness, perceived richness, and ecological characteristics.

		Reflection			Continuity with the past			Attachment		
	Taxonomic group	β	SE	r^2	β	SE	r^2	β	SE	r^2
Actual species richness (number of species)	Birds	.04	0.01	.16	.05	0.02	.16	.05	0.01	.20
	Butterflies									
	Plants	–.01	0.003	.19	–.01	0.003	.18	–.01	0.003	.18
Perceived richness (number of species)	Birds	.46	0.10	.38	.64	0.12	.45	.54	0.09	.41
	Butterflies	.47	0.18	.18	.63	0.23	.20	.52	0.21	.17
	Plants	.44	0.12	.31	.47	0.16	0.21	.51	0.17	.31
Ecological factor	Tree cover	.46	0.19	.16	.66	0.23	0.21	.68	0.24	.27
	Habitat diversity									

Note: Each pair-wise combination of variables was tested separately, and the resulting model, when more parsimonious than the null model on the basis of Akaike's information criteria (corrected for small sample sizes), is shown (β, parameter estimate; SE, standard error). In cases in which the null model offered the best explanation for the data, we assumed no relationship among the variables and no value appears in the table.

Finally, species richness in urban areas often peaks at intermediate levels of urbanization, likely because of high levels of habitat heterogeneity (Chace and Walsh 2006, McKinney 2008) but also perhaps driven in part by processes linked to the intermediate disturbance hypothesis (Connell 1978). Such areas are unlikely to have the most natural appearance to greenspace users, who may, therefore, not respond most favorably to sites that contain high species richness, especially since natural landscapes are, in general, preferred to built ones (Kaplan and Kaplan 1989, Herzog et al. 2000). Across our riparian sites, well-being did increase with tree cover, which could be interpreted as a proxy for naturalness (table 2). However, preferences for natural elements do not universally extend to urban landscapes and greenspaces (see Özgüner and Kendle 2006 and the references therein). Confounding factors can include characteristics that may indicate a lack of maintenance, such as the presence of litter (Özgüner and Kendle 2006, Kenwick et al. 2009). This was not found to be of consequence when included in this analysis, although well-being was negatively related to a litter index, perceived richness across all taxonomic groups remained an important predictor of well-being when they were included in the same models (supplemental appendix S3).

Identification skills

We wished to assess the ability of recreational greenspace users to correctly identify elements of the urban flora and fauna. The participants were therefore asked to label photographs of four species each of birds, butterflies, and plants. For all three taxonomic groups, the pictures represented three of the most widespread species (in the top 20%) recorded in the ecological surveys. The final image was of a species that was charismatic, straightforward for an ecologist to identify and that was less commonly found along the river corridors. We used the responses to generate continuous measures of wildlife knowledge by summing the number of correct responses to give a score between 0 and 12 for each participant.

Only two people (0.002%) correctly identified all of the images by providing the common or scientific name of the species, whereas 27.3% of the respondents could not accurately name a single species (figure 3). The most frequently recognized species were the blue tit (65.8%), a regular resident bird in domestic gardens, and the winter wren (39.2%), a common UK-breeding bird. In general, the greenspace visitors were better able to identify bird species (median number correctly identified = 1.38) than plant (0.32) or butterfly (0.29) species (table 1).

To investigate whether the participants with a good knowledge of wildlife were better at assessing levels of biodiversity, we developed an index to quantify the degree of mismatch between perceived and actual richness. For each taxonomic group, this ranged from 0 (the correct level was perceived) to 4 (perceived richness was four categories away from actual richness). When summed across all taxa to create a continuous measure, the degree-of-mismatch index had a theoretical maximum of 12 but, in practice, did not exceed 8. The participants' wildlife knowledge was negatively correlated with the degree of mismatch between perceived and actual richness (r_s = –.063, p = .047), indicating that as an individual's identification skills improved, so did their ability to accurately gauge levels of biodiversity, with those with the very best identification skills having a degree-of-mismatch index significantly lower than that of the other participants (supplemental appendix S4).

Conclusions

We anticipated that people would have a positive response to greater levels of species diversity (Fuller et al. 2007, Lindemann-Matties et al. 2010). However, there was no consistent relationship between human well-being and actual species richness. Indeed, well-being even decreased with increasing

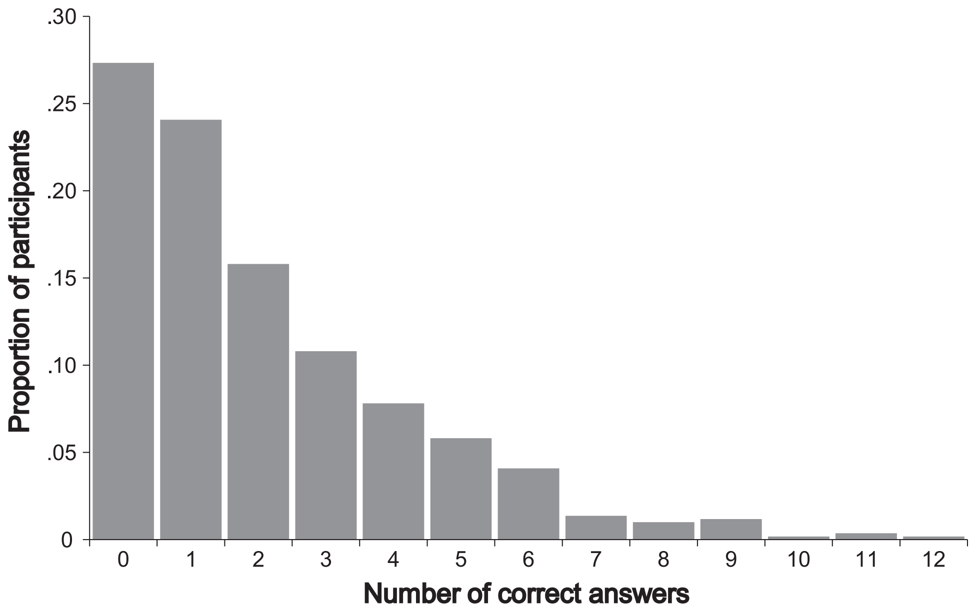

Figure 3. Number (out of a maximum of 12) of images of commonly encountered flora and fauna that were correctly identified by participants at all sites. The participants were presented with images of birds (blue tit,* Cyanistes caeruleus*; winter wren,* Troglodytes troglodytes*; gray wagtail,* Motacilla cinerea*; and dipper,* Cinclus cinclus*), butterflies (painted lady,* Vanessa cardui*; gatekeeper,* Pyronia tithonus*; speckled wood,* Pararge aegeria*; and peacock,* Inachis io*), and plants (cow parsley,* Anthriscus sylvestris*; broad-leaved helleborine,* Epipactis helleborine*; Herb-Robert,* Geranium robertianum*; and yellow archangel,* Lamiastrum galeobdolon*).

plant richness. This result supports the view that, in general, people have a limited capacity to perceive objective measures of the urban natural environment correctly (Leslie et al. 2010). For example, even though residents' perceptions of neighborhood "greenness" rarely equate to objective measures of vegetation quantity or quality (Hur et al. 2010), those who believe that their neighborhood had a high level of "greenness" are more likely to have better physical and mental health than those who think otherwise (Sugiyama et al. 2008). Perceptions of species richness itself can be hugely inaccurate (Dunning 1997, Lindemann-Matties and Bose 2008), which contrasts with the results from the visitors to public parks in Sheffield (Fuller et al. 2007) who were found to perceive relative levels of plant species richness correctly. Fuller and colleagues (2007) postulated that this was because plants are the most visible and static component of biodiversity. Our findings suggest that when users are in more ecologically complex and varied areas, such as the seminatural habitats that tend to characterize riparian zones, no consistent associations exist between actual and perceived richness. One hypothesis is that this disconnection between perception and reality may be a symptom of the lack of ecological knowledge in the developed world (Bebbington 2005, Pilgrim et al. 2008). Here, we demonstrate that the degree of mismatch between perceived and actual species richness grew as the greenspace users' ability to identify common elements of the local flora and fauna declined. Such a pattern must be a cause for concern, given the poor levels of wildlife knowledge reported in this study (figure 3).

One of the dominant messages of modern conservation biology is that biodiversity has an intrinsic value (Soulé 1985). Our findings show a positive relationship between three aspects of psychological well-being and greenspace users' perceptions of species richness, perhaps demonstrating the worth of biodiversity to the general public. However, there were no consistent interactions between well-being and actual species richness. With the exception of birds, people could not accurately assess the species richness of their surroundings. Visitors therefore gain well-being from locations that they perceive to be biodiverse, even if they are unable to identify which locations are actually more diverse.

Allying biodiversity conservation and the enhancement of public health as part of the urban greening agenda depends on a better understanding of the interactions between people and nature (James et al. 2009, Irvine et al. 2010). Evidence is rapidly accruing of the benefits that urban greenspaces have on the living conditions of the human populations of cities (Ward-Thompson 2002, Brown and Grant 2005), and greenspaces within cities can act as important refugia for biodiversity (Chace and Walsh 2006, McKinney 2008). Indeed, public policy in the United Kingdom (ODPM 2002) and elsewhere (e.g., EEA 2009) emphasizes the need for high-quality greenspaces as an additional component of urban form. However, our results indicate that there is no explicit link between species richness and the self-reported well-being of human inhabitants. Conservation biologists may therefore find that it becomes more challenging to mesh their priorities with other motivations for maintaining and enhancing greenspaces (Dearborn and Kark 2010) and that any one urban greenspace may not be able to maximize both the benefits to psychological well-being for the resident human population and biodiversity conservation, measured by species richness. Attention to strategies to provide more meaningful public engagement with nature may result in an increased ability of recreational greenspace users to recognize elements of the natural environment (Lindemann-Matthies 2006). Such action should help to align perceived and actual richness, thereby unlocking win–win scenarios in which the design and management of greenspaces can maximize both biodiversity conservation and human well-being.

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