Unpacking the People–Biodiversity Paradox: A Conceptual Framework

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Global phenomena, including urbanization, agricultural intensification, and biotic homogenization, have led to extensive ecosystem degradation, species extinctions, and, consequently, a reduction in biodiversity. However, although it is now widely asserted in the research, policy, and practice arenas that interacting with nature is fundamental to human health and well-being, there is a paucity of nuanced evidence characterizing how the living components of nature, biodiversity, play a role in this accepted truth. Understanding these human–biodiversity relationships is essential if the conservation agenda is to be aligned successfully with that of public health by policymakers and practitioners. Here, we show that an apparent "people–biodiversity paradox" is emerging from the literature, comprising a mismatch between (a) people's biodiversity preferences and how these inclinations relate to personal subjective well-being and (b) the limited ability of individuals to accurately perceive the biodiversity surrounding them. In addition, we present a conceptual framework for understanding the complexity underpinning human–biodiversity interactions.

Keywords: conservation biology, cultural ecosystem services, green space, human well-being, nature

Despite considerable effort on the part of conservationists, the biodiversity (box 1) extinction crisis shows no sign of abating, with human activities driving species losses worldwide (Cardinale et al. 2012). Solutions to stemming biodiversity loss will therefore depend on changing people's attitudes and behavior (Fuller and Irvine 2010, Duraiappah et al. 2013). However, the same global changes that threaten species and ecosystems, such as urbanization, agricultural intensification, and biotic homogenization, also modify the ways in which humans interact with nature in their day-to-day lives (Turner et al. 2004, Pilgrim et al. 2008). Human–nature interactions can be *intentional* (e.g., going to a park to feed birds or drawing trees *in situ* within a woodland), *incidental* (e.g., running across a beach and suddenly realizing you have been hearing birds calling or kicking up dead leaves as you walk although you are not cognizant of what you are doing at the time) or *indirect* (e.g., looking at images of butterflies in a book, watching a television documentary on brown bears or looking through a window to view a fox in the garden) (Keniger et al. 2013). In the highly urbanized societies that predominate in the developed—and increasingly developing—world, the human–nature interactions that occur are often restricted to green spaces (e.g., public parks and woodlands, riparian areas, and private gardens; box 1) within towns and cities (Fuller and Irvine 2010). Consequently, a number of authors have argued that people are becoming progressively "disconnected" from nature (e.g., Pyle 1978, Miller 2005).

The erosion of human–nature/biodiversity interactions is concerning for two reasons. First, such interactions are known to provide people with multiple benefits for health and well-being (box 1; Irvine and Warber 2002, Keniger et al. 2013, Hartig et al. 2014, Lovell et al. 2014). Second, some authors posit that an absence of contact with nature/biodiversity could contribute toward a lack of public interest and involvement in conservation (Miller 2005). Nonetheless, the first of these points may present an important opportunity for conservationists to leverage more support for policy and management interventions to protect and enhance biodiversity, thereby improving the frequency and/or quality of people's interactions with nature (Clark et al. 2014, Shwartz et al. 2014a). If these opportunities can be capitalized on, they might bestow additional positive co-benefits by increasing public engagement in conservation.

The prevalence and costs associated with treating poor mental health and noncommunicable diseases (e.g., diabetes, cardiovascular disease and depression) are expanding worldwide, particularly in developed nations (WHO 2014). As such, the beneficial outcomes associated with human–nature/biodiversity interactions (e.g., stress reduction, Peschardt and Stigsdotter 2013; improved physical exercise, Pretty et al. 2005; and lower depression, Marselle et al. 2014), which can help in combatting these issues, are of interest to the health sector (Coutts et al. 2014). Through carefully targeted interventions, such as strategically optimizing access to urban green spaces of high ecological

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Box 1. Key terminology.

Biodiversity	The variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems	Convention on Biological Diversity (*www.cbd.int/convention/articles/default.shtml?a=cbd-02*)
Green space	Open, undeveloped land with natural vegetation	Centers for Disease Control and Prevention (*www.cdc.gov/healthyplaces/terminology.htm*)
Novel ecosystem	Ecosystems that have been heavily modified by humans, and differ in composition and/or function from present and past systems	Hobbs et al. 2009
Human health	A complete state of physical, mental, and social well-being, and not merely the absence of disease or infirmity	World Health Organization WHO 1948
Human well-being	(Subjective) well-being encompasses different aspects: cognitive evaluations of one's life, happiness, satisfaction, positive emotions such as joy and pride, and negative emotions such as pain and worry	Stiglitz et al. 2009
Species richness	The number of species observed in a defined geographic location	Begon et al. 2006

quality across heavily populated landscapes, relatively small gains at an individual level could scale-up to substantial cost-effective benefits across entire populations, even in comparison with approaches focused specifically on people with higher health risks (Dean et al. 2011). Investment in biodiversity could therefore be considered a worthwhile societal prophylactic, reducing the economic and human costs of ill health (Sandifer et al. 2015).

Given that practitioners and policymakers tasked with managing human-dominated landscapes have to deliver and trade-off between multiple biodiversity, individual, and societal benefits (Reyers et al. 2012), environmental interventions that deliver mutually reinforcing outcomes for both biodiversity conservation and people are highly desirable. Before such scenarios can be pushed forward, it is vital to understand the role played by biodiversity *per se*—rather than by the more nebulously defined "nature"—in producing measurable health and well-being benefits for individuals and, in turn, the wider population. In this article, we discuss the complex relationship between biodiversity and human health and well-being, which is emerging from a growing international literature (e.g., Lovell et al. 2014), highlighting the "people–biodiversity paradox" (Fuller and Irvine 2010, Shwartz et al. 2014b, p. 87). In addition, we present a conceptual framework that, like others in the ecological public health paradigm (Coutts et al. 2014), can be a useful tool in communicating these concepts across the different research disciplines required to unpack this paradox. The people–biodiversity paradox differs conceptually from the "environmentalists' paradox" (Raudsepp-Hearne et al. 2010) in terms of both scale (the former is at the level of the individual, whereas the latter is global) and what is being measured (individual perceptions or subjective well-being in response to personal interactions with biodiversity versus objective well-being and the state of ecosystem-service provision).

How does biodiversity underpin human well-being?

Despite ecosystem assessments being the prominent lens through which nature is valued and incorporated into decision-making (MA 2005, UKNEA 2011), our knowledge of how biodiversity underpins ecosystem functioning and services remains limited (Mace et al. 2012). This is especially true for nonmaterial cultural ecosystem services (e.g., aesthetics, spiritual enrichment, recreation and reflection), where the relationships have rarely been investigated (Cardinale et al. 2012). How biodiversity underpins mental and physical health is less clear still and has proven harder to quantify reliably (Clark et al. 2014).

Few studies directly consider how variation in the "quality" of environmental spaces, as is measured by ecologists, affects human well-being and individual preferences for certain elements of biodiversity (see Lovell et al. 2014 for a review). For example, epidemiological research has typically considered the size and distribution of green space surrounding properties and the influence these have on the health and well-being of an individual (e.g., de Vries et al. 2003, Mitchell and Popham 2008). Although this work provides valuable insights regarding green space accessibility or proximity across a population and the associated health and well-being benefits this might confer, it assumes that the spaces are homogenous entities and does not tease apart ecological complexity in terms of, for instance, species richness (box 1), community assemblages, or land-cover diversity (Wheeler et al. 2015). Indeed, we know little about which aspects of biodiversity trigger the positive human well-being benefits reported in studies to date. Furthermore, it is highly improbable that all species and ecological traits—and the different compositions of these various attributes—will be advantageous or deleterious for health and well-being, particularly as responses are likely to be moderated by an array of contextual, social, and cultural filters. Future research should therefore explicitly consider measures of ecological quality alongside individual health and well-being outcomes.

Studies that have examined objective metrics of biodiversity (e.g., species richness and abundance) are inconclusive, identifying an inconsistent and complex relationship between biodiversity and self-reported human health and well-being. They reveal a "people–biodiversity paradox" (Fuller and Irvine 2010, Shwartz et al. 2014b, p. 87), comprising a mismatch between (a) people's biodiversity preferences and how these inclinations relate to personal subjective well-being and (b) the limited ability of individuals to accurately perceive the biodiversity surrounding them.

Several papers highlight people's preferences for greater species richness, a finding that has been repeated across a range of habitats, including urban gardens (Lindemann-Matthies and Marty 2013), grasslands (Lindemann-Matthies et al. 2010a), and green roofs (Fernandez-Cañero et al. 2013), as well as in bird song (Hedblom et al. 2014). Fuller and colleagues (2007) found that self-reported psychological well-being was associated positively with plant species richness and that people could accurately perceive levels of diversity for this taxon, although this relationship was less evident for birds and not found for butterflies. Dallimer and colleagues (2012) found no consistent relationship between plant or butterfly species richness and self-reported psychological well-being within an urban riparian environmental spaces, although a positive trend was apparent for avian diversity. Intriguingly, however, well-being was positively related to the perceived richness of all three taxonomic groups. A similar inconsistency was noted by Shwartz and colleagues (2014b), who discovered that people could not detect increases in flowering plant, bird, or pollinator richness after experimental manipulations within public gardens, and considerably underestimated levels of diversity. Nonetheless, individuals expressed a strong preference for species richness in these green spaces and related the presence of diversity to their well-being. At a neighborhood scale, Luck and colleagues (2011) found a strong positive relationship between vegetation cover and self-reported well-being. However, the authors found demographic characteristics explained a greater proportion of the variation in well-being.

The people–biodiversity paradox is also evident within the literature examining individual's landscape preferences and attitudes toward biodiversity. For example, when investigating attitudes toward field margins in Swiss agricultural landscapes, Junge and colleagues (2009) found that people expressed a greater appreciation for margins where they estimated plant species richness was higher. Yet, the actual plant richness of the field margins did not influence appreciation. Therefore, as was true of the urban green space studies highlighted above, people's predilections appear to be driven by the biodiversity they perceive to be present. However, there are exceptions. Qiu and colleagues (2013) discovered that people could correctly estimate the differences in plant diversity across habitats and that the species richness of this taxon was not related to preference, with open park locations rated more highly than areas of more complex vegetation. Likewise, Shanahan and colleagues (2015a) found that people do not preferentially visit parks with higher tree and vegetation cover, despite these areas having the potential for enhanced experiences of biodiversity.

The disparities outlined above may be a consequence of ecological factors such as spatial scale, taxonomic group, and the metrics used to measure biodiversity. Findings at a broad scale (i.e., asking people to rank images of landscapes by the level of human disturbance) indicate that people can reliably identify differences in landscape intactness (Bayne et al. 2012) but fail to estimate the objective level of greenness of their neighborhood (Leslie et al. 2010). Although Lindemann-Matthies and colleagues (2010b) reported a positive relationship between plant species richness and individual aesthetic preferences, the spatial distribution of the plants was also found to influence appreciation. In addition, plant communities consisting of the same number of species were perceived to be more species-rich when evenness (the relative abundance of different species) was higher (Lindemann-Matthies et al. 2010b). This suggests that species richness alone may not be the best measure of biodiversity when considering human responses to, and appreciation of, biodiversity. Indeed, this is understandable, because many species cannot be detected without specialist training (e.g., because they are difficult to identify) or without a great deal of effort (e.g., because of their elusive behavior). When unpicking the people–biodiversity paradox, researchers should consider using a suite of more resolved biodiversity metrics (e.g., abundance, evenness, and functional diversity) to determine the ecological quality of environmental green spaces (Lovell et al. 2014).

Explicit consideration of the complexity associated with human well-being and biodiversity

It is possible that the emerging people–biodiversity paradox is a result of the multidimensionality of both biodiversity and human well-being, making it difficult to account for and measure the complex social and ecological characteristics that may influence the outcome of interactions (Hartig et al. 2014, Lovell et al. 2014). The concepts of health and well-being are just as multifarious as that of ecological quality, incorporating a wealth of different aspects of human physiological, cognitive, emotional, social, and spiritual wellness, and studies have explored these facets

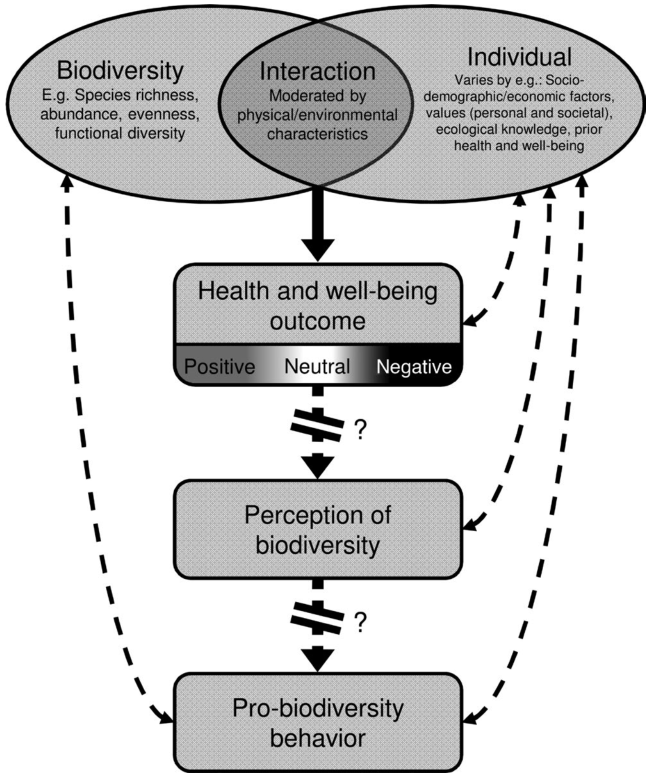

Figure 1. Conceptual framework of human–biodiversity interactions and potential outcomes for health and well-being, perceptions of biodiversity and pro-biodiversity behavior. Human–biodiversity interactions can lead to a cascade of potential outcomes. The question marks represent less well-understood relationships. The dotted lines represent feedback from outcomes back to biodiversity or the individual.

from several disciplinary perspectives (Irvine and Warber 2002, Keniger et al. 2013, Irvine et al. 2013). Heterogeneity in research design, and the use of different ecological and well-being measures, thus reflect the complexity that social and natural scientists are grappling with in trying to understand how people derive benefits from interacting with nature/biodiversity. Our conceptual framework (figure 1) illustrates that such interactions could generate outcomes for an individual's health and well-being, and, in turn, this might relate to human perceptions of—and behaviors toward—biodiversity.

The type and intent of the human–biodiversity interaction are likely to influence the outcome (Church et al. 2014), which might be positive, neutral or negative (figure 1). In addition, experiences of biodiversity can be influenced by physical or environmental characteristics associated with the point of interaction, such as the season and prevailing weather conditions (figure 1, table 1). These filters are often ignored in research projects but are potentially important determinants of outcomes (White et al. 2014). Although the majority of studies conducted on human–nature or human–biodiversity interactions thus far have concentrated on the benefits gained by people, disservices also require research attention (Dunn 2010), because practitioners and policymakers need to be able to make fully informed decisions in a land-use planning and management context (Lyytimäki and Sipilä 2009). At the most extreme, interactions with biodiversity can lead to death and injury, for instance, through attacks from predators or via the contraction of pathogens. Human–wildlife conflict can also lead to diminished health and well-being in addition to physical injury or pathology (Barua et al. 2013) and, in an urban context, close contact with nature has been associated with fear, disgust, and discomfort (Bixler and Floyd 1997).

The outcome of an interaction with biodiversity can feed back to the individual (figure 1), changing aspects of their ecological knowledge, values, and underlying health and well-being. Indeed, a particular interaction might be perceived as positive or negative depending on the individual making the evaluation (Buchel and Frantzeskaki 2015). In turn, this could contribute to the likelihood that the individual will subsequently interact with biodiversity and may influence future outcomes (e.g., positive interactions might predispose future outcomes to being more positive and vice versa). A suite of individual characteristics can moderate both the magnitude and direction of an outcome, as well as the probability that an interaction will take place (figure 1, table 2). To illustrate, a review of fear of crime experienced in urban green spaces found variability in responses according to factors such as age, gender, socioeconomic status, frequency of visits, and familiarity with the site, as well as the biophysical attributes of the areas (Maruthaveeran and van den Bosch 2014). Cultural factors are also likely to be important. A recent paper by Lindemann-Matthies and colleagues (2014) demonstrated that a cohort of Chinese people did not show a preference for biodiverse forest, whereas the comparative Swiss participants favored species-rich forest over monoculture. Similarly, a study in Singapore found that neither access to nor use of green spaces influenced measures of well-being (Saw et al. 2015). There is a paucity of such cross-cultural studies, with most work on human–nature or human–biodiversity interactions being geographically biased toward industrialized regions of the Global North (Keniger et al. 2013). This hinders our understanding, and there is a need for greater focus on biodiversity-rich countries where urban development is accelerating rapidly (Lindemann-Matthies et al. 2014).

How frequently people choose to visit green spaces, if at all, can be influenced by both the characteristics of individuals (table 2), as well as the accessibility or proximity of the green space (table 1). The contribution of these different sets of attributes appears to be variable, with contradictory results reported in studies. For example, people's nature orientation—that is, the affective, cognitive, and experiential relationship they have with the natural world—has been shown by some to be more important in determining time spent in urban green spaces than the availability of nearby

Table 1. Illustrative physical/environmental characteristics that could influence the likelihood that people will interact with nature/biodiversity and the outcome of such interactions.

Characteristic	Description and supporting examples
Season	Seasonal changes affect the well-being of office workers (Hitchings 2010).
Weather	Landscape preferences are influenced by climatic conditions (White et al. 2014).
Accessibility	People who report that they have easy access to green spaces use green spaces more regularly (Hillsdon et al. 2011).
Proximity	People with less green space in close proximity to their home reported greater loneliness and a perceived shortage of social support (Maas et al. 2009). Populations exposed to the greenest environments have the lowest levels of health inequalities (Mitchell and Popham 2008). People visit more frequently when it takes less time to reach a green space (Dallimer et al. 2014).

green space (Lin et al. 2014). Conversely, others report that proximity and the time it takes individuals to reach a site are stronger predictors of visit frequency (Dallimer et al. 2014). The visit duration can also influence the outcome of interactions (a dose–response relationship), with research typically finding a positive relationship between the time spent in a green space and the response (White et al. 2013). However, others have found less straightforward dose–response relationships. For instance, Barton and Pretty (2010) found diminishing but still positive mental health returns from higher-intensity and longer-duration green exercise, whereas Shanahan and colleagues (2015b) suggested several potential dose–response relationships.

A further complexity that requires careful consideration is that spending time in green spaces can be beneficial to individuals, not necessarily because of interaction with biodiversity but by virtue of the fact that it encourages and facilitates behaviors that are known to be mentally and physical favorable, such as exercise and social interaction. It is therefore important to evaluate the extent to which human–biodiversity interactions provide added value. Research into green exercise, for example, has shown that there are synergistic benefits associated with taking part in physical activities while viewing nature (Pretty et al. 2005).

What are the consequences of the people–biodiversity paradox for conservation?

If, as recent studies suggest, human–biodiversity interaction outcomes are influenced by people's perceptions of biodiversity rather than by objective measures, the role of ecological knowledge in influencing the relationship is a key dimension worthy of consideration. The lack of ecological knowledge in developed world citizens (Pilgrim et al. 2008, Dallimer et al. 2012) might support authors' assertions that there is a growing "disconnection" between people and nature (Pyle 1978, Turner et al. 2004, Miller 2005). They propose that an "extinction of experience" is occurring because individuals are increasingly isolated from nature in their everyday lives and, as such, they have less impetus to protect and experience nature, leading to a vicious, deleterious cycle. Social or education interventions have been advocated as a means to reverse this negative feedback. For instance, research has shown that people with more taxonomic knowledge express preferences for more species-rich flower meadows (Lindemann-Matthies and Bose 2007), and children who participated in an educational program had an increased appreciation of local nature (Lindemann-Matthies 2005). However, questions remain as to whether such interventions have a long-term impact on levels of interest and engagement with biodiversity (Shwartz et al. 2012).

If people are only responding positively to certain traits and assemblages of species, it is possible that these might not be the biodiversity elements that conservationists would wish to support. Urban areas are highly susceptible to biotic homogenization and harbor many nonnative species (McKinney 2002). As yet, it is still unclear whether the nativeness of species makes a difference to the well-being response an individual receives from an interaction. People may value species that they know to be native more (Lundhede et al. 2014), although nonnative species may possess traits (e.g., larger in body size, more colorful, or behaviorally distinct) that people prefer (Frynta et al. 2010). This could present a potential challenge and conflict for conservationists and practitioners, who may seek to promote native taxa through the management of nonnative species but who also need to encourage the health and well-being benefits that may be gained from interacting with charismatic nonnative species. A better understanding of the public perception of nonnative species could feed usefully into the ongoing debates on the legitimacy of the novel ecosystem (box 1) concept (Hobbs et al. 2006, Kowarik 2011), as well as providing an evidence base for land-use planning, management, and decisionmaking.

Even if future research continues to corroborate the advantages people can gain from interacting with biodiversity, individuals might not consciously relate these benefits to biodiversity *per se*. If this is the case, there is no reason to expect an individual's perception of biodiversity to alter as a consequence human–biodiversity interactions and, subsequently, to presume a shift toward more pro-biodiversity behavior. Indeed, positive attitudes toward biodiversity alone do not translate into pro-biodiversity behaviors (figure 1; Waylen et al. 2009), being modified by numerous external as well as internal factors, including subjective norms, facilitating factors and moral obligations (Clayton and Myers 2009). Much more research is needed to discern the links between

Table 2. Illustrative individual characteristics which could influence the likelihood that people will interact with nature/biodiversity, and the outcome of such interactions.

Characteristic	Description and supporting examples
Gender	Gender differences have been observed in associations between urban green space and health outcomes (Richardson and Mitchell 2010). Women demonstrate a preference for higher plant species richness than men do (Lindemann-Matthies and Bose 2007, Lindemann-Matthies et al. 2010a).
Age	Proximity to green space has a greater influence on the health of the elderly than other age groups (de Vries et al. 2003). Older people prefer species rich field margins (Junge et al. 2009) and meadows (Lindemann-Matthies and Bose 2007).
Education	Health benefits from proximity to green space are greater for people with a lower level of completed formal education (de Vries et al. 2003).
Sociodemographic/ economic factors	There are racial and economic inequalities regarding access to biodiversity; for example, fewer native birds have been found in neighborhoods composed predominantly of Hispanic and lower-income people (Lerman and Warren 2012).
Home location	People who identify themselves as “urban” report lower levels of restoration from images of nature than ‘rural’ individuals (Wilkie and Stavridou 2013).
Culture	Chinese study participants demonstrate no strong preferences for biodiversity when compared with Swiss participants, who favored species-rich forests over monocultures (Lindemann-Matties et al. 2014). The well-being of residents in Singapore was not affected by access to, or the use of, green spaces (Saw et al. 2015).
Childhood experience	People who spent their childhood in a more natural environment show a greater preference for green roofs over gravel (Fernandez-Cañero et al. 2013).
Connectedness to nature	Residents living in neighborhoods with greater richness and abundance of bird species and density of plants had a higher connection to nature (Luck et al. 2011).
Ecological knowledge	Children who participated in an educational program had increased appreciation of local nature (Lindemann-Matthies 2005). People with better wildlife identification skills were able to more accurately estimate the species richness of surrounding vegetation, birds and butterflies (Dallimer et al. 2012).
Intention	Although interacting with nature is beneficial to urban park visitors, it was not a main motivation for visiting (Irvine et al. 2013). Frequent users of urban green spaces state motivations relating to physical activities, whereas infrequent users motivations are more associated to the quality of the space (Dallimer et al. 2014).
Social interaction	Individuals who visited natural areas accompanied by children experienced less restoration than those who were alone (White et al. 2013). Fear of crime influences some individuals to avoid urban green spaces (Maruthaveeran and van den Bosch 2014)
State of mind	Urban green spaces which are perceived to contain more nature are also perceived to be more restorative by stressed individuals (Peschardt and Stigsdotter 2013).

exposure to biodiversity and how this might, ultimately, lead to shifts in underlying attitudes and behavior. Beyond education, understanding what individuals perceive as constituting a preferable biodiverse environment will allow for human-modified landscapes to be designed in a manner that delivers benefits to both people and biodiversity.

Conclusions

The examples presented here of the people–biodiversity paradox illustrate the need for careful consideration before a straightforward relationship between increased biodiversity and improved human well-being can be implied. If we wish to align the agendas of public health and biodiversity conservation, we first need to understand the mechanisms behind the people–biodiversity paradox and the added value that enhanced people–biodiversity interactions can deliver for conservation. Well-designed and carefully conducted interdisciplinary research, which genuinely bridges traditional disciplinary boundaries, will be the key to effectively unpacking this paradox.

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