Biodiversity and human well-being: the value of human-nature interactions for people and conservation

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Dedicated to the memories of my grandfathers
Harold Jones and Lawrence Pett.
For taking me to play on the farm and in rivers and inspiring in me
a life-long love of the natural world.

"I feed the pigeons, I sometimes feed the sparrows too,
It gives me a sense of enormous well-being"
Blur, *"Parklife",* 1994.

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Author's declaration

T.J. Pett wrote all of the chapters, with editorial suggestion made by PhD supervisors D.L. Roberts and Z.G. Davies. Chapters 2-6 include collaborations with researchers external to the University of Kent as outlined below.

Chapter 2 originated during discussions with A. Shwartz, K.N. Irvine, M. Dallimer and Z.G. Davies. T.J. Pett wrote the manuscript with comments and feedback from co-authors and two anonymous reviewers for the journal *BioScience*.

Chapter 3 originated during discussions with Z.G. Davies, M. Dallimer and T.H. Lundhede. The sampling design and questionnaire was developed with collaborative input from all co-authors. All data analyses were conducted by T.J. Pett with NLogit programming support from T.H. Lundhede and M. Dallimer. T.J. Pett wrote the chapter with collaborative input from all co-authors. Further amendments to the manuscript were made by all co-authors based on feedback from two anonymous reviewers for the journal *Ecological Applications*.

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Abstract

Over the past century the human population has rapidly expanded and people have moved from rural to urban areas. More than half of all people now live in towns and cities. In high-income regions, such as Western Europe, this proportion is much higher and, for many people, the principal place they encounter biodiversity is within urban areas. As a result of biodiversity declines, it has been argued that people are becoming increasingly disconnected from nature. This is concerning as there is a growing body of evidence that links interacting with nature with multiple benefits for human health and well-being. Such benefits are also of particular interest for conservationists, who wish to better align the maintenance of biodiversity in human dominated landscapes with the public health agenda in order to leverage funding and support. However, there has so far been a lack of nuanced evidence characterising how biodiversity *per se* plays a role in providing these benefits. Through a series of case studies from different study systems, this thesis investigates some of the specific attributes of biodiversity that people perceive, prefer, value and gain benefits from. This is done through employing novel interdisciplinary methodologies, combining approaches from ecology, economics, psychology, public health and conservation social science. Through these studies the potentials for win-wins and trade-offs in interventions designed for biodiversity conservation and human well-being, are also explored. First, people's values towards native and non-native bird species, and their management, are identified and it is found that people's familiarity with species, and perceptions of species attractiveness, is of greater importance to their preferences than whether a species is native or not. Second, people's perceptions and values towards wildflower meadows, planted for the benefit of pollinators in urban greenspaces, are quantified. It is found that people could generally perceive ecological characteristics, such as species richness, but this did not influence their self-reported connection to nature. Thirdly, the same flower meadows study system is used to explore people's preferences for increases in biodiversity, investigating how people value sites for varying functional and aesthetic features, and how these values vary due to people's connectedness to nature. The final study considers the relationship between access to greenspaces and people's level of physical activity, finding an importance of site naturalness for certain human populations. Each of these findings has implications for the design of conservation interventions, which must consider how people perceive and value biodiversity in order to achieve successful outcomes. Each chapter also contributes to the advancement and validation of methodologies within this multidisciplinary field. Overall, this thesis addresses key knowledge gaps in understanding human-biodiversity interactions and suggest that there is a more complex relationship between biodiversity, well-being and connection to nature than is sometimes assumed. These complexities must be better considered within socio-ecological research, and ultimately within ecological management, in order to maximise the potential for win-wins for biodiversity conservation and people.

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Chapter 1. General introduction

1.1. A changing world for people and nature

The planet is undergoing the largest and fastest period of transformation in human history. The last century has seen dramatic changes to the way the human population lives, with 55% of the world's population now residing in towns and cities rather than rural areas (United Nations, 2018). This change in the global structure of the human population is set to continue, from just 30% of people living in urban areas in 1950, projected to reach 68% by 2050 (United Nations, 2018). This upward shift in the percentage living in urban areas, alongside an overall population increase, means that there will be around 2.5 billion new urban inhabitants by 2050 (United Nations, 2018). Although currently only representing around 3% of landcover (Liu et al., 2014), urban land is expanding faster than any other land-use type, at rates at least twice as fast as urban population growth, and in some places up to four times faster (Angel et al., 2011; Seto et al., 2011). Cities and towns generate around 80% of the world's economy (Grubler et al., 2012) and contribute over 70% of energy use and energy-related emissions (Seto et al., 2014). Therefore, although they are only a relatively small proportion of the total Earth surface, urban areas make a vast contribution to environmental change.

The relationship between urbanisation and biodiversity conservation is complex and multifaceted. On the one hand, urban development destroys and fragments natural habitats and is a significant factor in current and predicted species extinctions at local to global scales (Grimm et al., 2008; McDonald et al., 2008). Human population density tends to be higher in high productivity landscapes where it is easier to grow food, whilst also being high in biodiversity (Luck, 2007). This spatial correlation between cities and areas of high biodiversity means the impact of cities on biodiversity globally is much larger than their footprint, with one study showing that although cities only occupy ~3% of landcover, they impact around 13% of the world's vertebrates (McDonald et al., 2008). On the other hand, increases in the efficiency of resource use associated with urbanisation, especially when built densely, can be a net positive for the environment, reducing per capita environmental footprints, and partially 'decoupling' society from environmental damage (McDonald, 2015). Alongside this, although urbanisation typically results in a reduction in biodiversity, the greenspaces left within urban areas are increasingly becoming an important refuge for some species, due to decreases in rural habitat quality owing to agricultural intensification (Benton et al., 2003; Goddard et al., 2010). However urban biodiversity is typically restricted to highly fragmented and degraded habitat patches, leading to an overall reduction in the number and diversity of species, as the remaining habitat is unable to support complex ecological communities (Grimm et al., 2008).

Urbanisation is just one of many anthropogenic drivers of biodiversity loss (Dirzo et al., 2014). Indeed, the wave of extinction triggered by the cumulation of human activities may be comparable in magnitude to, and at a much higher rate than, the five previous mass extinctions of Earth's history (Barnosky et al., 2011). These major environmental changes are happening rapidly, yet, so far, we have limited understanding of the direct implications of this change for to people. Human health and well-being has been described as the ultimate or cumulative ecosystem service (Sandifer et al., 2015); and the Millennium Ecosystem Assessment has identified multiple direct and indirect pathways through which the natural environment influences health (MEA, 2005). Yet despite this recognition within the environmental policy agenda, the links between health and environments has received relatively little direct attention. Health, defined as, 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO, 1948), is determined by factors beyond those of individual characteristics and behaviours (WHO 2019). Thus, many other determinants combine together to influence the health of individuals and communities, including the social economic and physical environment (Barton and Grant, 2006).

Urbanisation is considered one of the most important health challenges of the 21st century (WHO, 2015). Urban lifestyles have been associated with an increase in the prevalence and costs associated with chronic and non-communicable conditions, such as stress, mental ill health and a lack of physical activity (Dye, 2008). The loss of nature in cities is of particular concern to these health challenges, as increasingly research has shown that a breadth of health and well-being outcomes are associated with exposure to the natural world including stress reduction (White et al., 2013), improved physical exercise, (Pretty et al., 2005) and lower depression (Marselle et al., 2014). It is estimated that if every household in England had good access to greenspace, £2.1 billion would be saved annually through averted NHS costs (Natural England, 2009) and the 'use of nature' has been recognised by the UK Department of Health (2013) as a determinant of public health. So far however, only a handful of studies have actually considered how biodiversity in particular plays a role in conferring benefits to health and well-being, and overall the evidence is inconclusive (Lovell et al., 2014). This theme is explored further in **Chapter 2** (Pett et al., 2016).

1.2. Key concepts and methodological approaches

Within the context of these rapid environmental and social changes, research has increasingly attempted to characterise how people perceive, value and benefit from nature (Botzat et al., 2016; Ives et al., 2017). Although grounded within conservation science, this thesis makes use of methodologies from, and delves in to, many of these wider disciplines, especially those from the social sciences. This is in the tradition of how social science has become progressively integrated into conservation science, due to the increasing recognition that engaging in the human dimensions of conservation and environmental management is needed to produce effective conservation policies, actions and outcomes (Soulé, 1985; Kareiva and Marvier, 2012; Sandbrook et al., 2013; Bennett et al., 2017). In this section I introduce key concepts and methodologies employed in this thesis.

1.2.1. Theories and concepts describing human-nature relationships

A number of theories describe human-nature connections, and these provide the framework for understanding how the natural environments may promote well-being. One of the earliest formal conceptions of a human need for contact with nature is the biophilia (meaning love of life) hypothesis (Wilson, 1984; Kellert and Wilson, 1993). The main proposition of the biophilia hypothesis is that human affiliation to nature is universally innate due to our evolution amongst nature. The model of biophilia underpins a lot of the early work to research and promote interactions between people and nature, especially within environmental psychology (e.g. Kahn and Kellert, 2002). Biophilia was further extended in the 1980's and 90's by the proposition that humans have a pre-cognitive positive response to natural scenes, in the same way humans and non-human primates have a pre-cognitive response to negative stimuli (a fight-or-flight response) (Ulrich, 1983). The theory states that many qualities inherent in natural environments may help to aid people's recovery from stress, and that humans have not had the time to evolve comparable responses to urban environments. By extension, it is hypothesised that human created urban environments do not contain the same restorative potential from stressful events as natural environments.

A more recently developed concept, the 'extinction of experience' (Pyle, 1993; Soga and Gaston, 2016) posits that urbanisation and other processes lead to a loss of interactions with nature, and subsequently a diminishing of associated health benefits, as well as positive emotions, attitudes and behaviours. Increasing urbanisation and shift in peoples lifestyles has led to a 'disconnection' from nature for the majority of urban dwellers (Turner et al. 2004). As more and more people are living in highly modified, human-dominated environments, ecological processes are now hidden from human view. Disconnection from nature has led to a lack of support for biodiversity conservation, as 'collective ignorance leads to collective indifference' (Miller, 2005). It is argued that if there is to be broad-based public support for conservation, opportunities for meaningful interactions with the natural world should be provided in the places that people live and work. As well as raising public support, this reconnection with nature has the potential to enhance human well-being (Soga and Gaston, 2016). The extinction of experience could cause a potential vicious cycle whereby people become more disconnected from nature and therefore have less awareness or attachment to the natural world. This could mean that people have less interest in the conservation or protection of nature, causing further deterioration and therefore further disconnection (Soga and Gaston, 2016).

1.2.2. Psychological constructs of nature connectedness

A number of different theories and terms related to human 'connections' to nature have emerged from different disciplines (Zylstra et al., 2014; Ives et al., 2017). Indeed, calls for society to 'reconnect with nature' have become increasingly common in the scientific and environmental literature, and the perceived separation is viewed as a drive behind the environmental crisis (e.g. Pyle, 2003; Balmford and Cowling, 2006; Tam, 2013). Multiple psychological 'instruments' have been developed within environmental psychology to attempt to measure different dimensions of connections between people and nature (reviewed in Zylstra et al., 2014). One of the more frequently used of these is the Connectedness to Nature Scale (CNS). The CNS seeks to measure an individual's conscious, stated level of emotional relatedness and kinship with nature (Bratman et al., 2012). In environmental psychology studies, CNS has been shown to be a predictor of other measures, such as identifying oneself as an environmentalist and subjective well-being measures including life satisfaction and overall happiness (Mayer and Frantz, 2004; Mayer et al., 2009, Tam, 2013). CNS was originally proposed as a 'trait' measure, describing an aspect of personality (Mayer and Frantz, 2004), however it has also been adapted to be deployed as a 'state' response that can be used to measure an individual's response to situations, such as exposure to different environments (Bragg et al., 2013; Mayer et al., 2009). The measure has been shown to be internally consistent through test—retest, and its correlation with other related instruments, and therefore is considered reliable and valid (Mayer and Frantz, 2004; Zylstra, et al., 2014). Research into connections with nature does not typically specify the characteristics of nature that people are connected to, but without such information it is difficult to know how policies and decisions to maximise benefits should be formulated (Ives et al., 2017).

Although some of the initial emerging evidence on connection to nature is promising on how the construct is linked to environmental behaviour and human well-being outcomes, it is important also to note that the current evidence base is small and studies are not often conducted in a way that allows for causality to be understood (Natural England, 2016). More broadly the overarching narrative of 'reconnection to nature' has received some criticism for paradoxically enforcing a sense of separation between people and nature, questioning its use and validity (Fletcher, 2016). Some healthy scepticism about the utility of the 'reconnection to nature' narrative is important, especially as the concept is being increasingly operationalised by environmental non-governmental organisations (e.g. RPSB, 2019; National Trust 2019), and government agencies (Natural England, 2017). However, this integration into policy is also a reason that this concept requires further research.

1.2.3. Ecosystem services and valuing nature

Another key concept that has received increasing research and policy attention is that of ecosystem services, i.e. the benefits people obtain from ecological systems. Ecosystem services can be broadly classified into provisioning, regulating and cultural services (CICES, 2018). Quantifying ecosystem services is relatively straightforward in the case of provisioning services that people directly use (e.g. timber production). However, cultural ecosystem services, the non-material benefits that people gain from ecosystems, are less tangible and more difficult to quantify. Six aspects of cultural ecosystem services were identified within the Millennium Ecosystem Assessment; cultural identity, heritage values, spiritual services, inspiration, aesthetic appreciation, recreation and tourism (Church et al., 2011; MEA, 2005). Although the importance of biodiversity to cultural services is widely cited (e.g. Haase et al., 2014; Schwarz et al., 2017), there is a lack of evidence on how, and which constituents of, biodiversity actually lead to the delivery of services (Botzat et al., 2016). Further, due to the challenges inherent in valuing cultural ecosystem services, they are underrepresented in ecosystem service studies (Boerema et al., 2016; Gee and Burkhard, 2010).

Another broad concept that is of relevance to the study of people's relationship with nature is the concept of values. Values are becoming increasingly prominent within environmental decision making, with increasing recognition that environmental outcomes depend on socio-political factors, including the way people think about the environment (Mascia et al., 2003). Ascribing values to biodiversity and ecosystem services ensures they are given greater consideration in decision making. There are many different approaches to the study of values, distinguished between different disciplines and philosophical viewpoints (Ives and Kendal, 2014; Keeler et al., 2019). Psychologists and sociologists mostly refer to the *values of* people referring to their preferences for particular means or ends (Ives and Kendal, 2014). Values in this sense are underlying characteristics of people that shape the judgements they make about the world around them. A different conception of values is the way things in the world are *valued by* people. In this sense, values represent the relative worth of a thing, place or experience (Bengston, 1994). This second conception of values is the one typically used by environmental economists.

As there are limited resources available for the conservation of biodiversity and ecosystem services, there is a need to understand people's preferences for different aspects of the natural world, as one dimension of prioritisation of actions. Valuation in an economic context is therefore a way to understand how much something is worth to people (Ozdemiroglu and Hails, 2016). In principle any units can be used within economic valuation, however monetary terms are often used due to their comparability and familiarity. This commensurability is the ability for measured values to be reduced to a single scale of measurement that allows them to be compared directly (Bengston, 1994). This allows for direct comparison with other costs and benefits to be used within decision-making processes (MEA, 2005; UKNEA, 2011).

Multiple approaches to the measurement of economic value exist, and the appropriate approach to use depends on the what is being measured. As cultural ecosystem services (such as aesthetic appreciation and recreation) are often not values for which are traded within markets, their values are often estimated using stated preference approaches (Ozdemiroglu and Hails, 2016). As well as measuring use values, stated preferences techniques are unique, in that they are the only economic valuation method that can estimate non-use values. This is typically done by presenting people with choices directly through carefully designed questionnaires. Choice experiments are a standard method to derive estimates of people's willingness to pay for changes to biodiversity (e.g. Christie et al., 2006; Hanley and Barbier, 2009). These involve presenting respondents with choices between environmental changes that involve different costs and asking them to choose their preferred option. A key underlying assumption to the measurement of values through econometric approaches like choice experiments, is that people are rational actors, who when making decisions judge all possible outcomes, and choose the one which maximises their individual wants or needs (referred to as utility) (Lancaster, 1966; McFadden, 1974).Therefore the subjective values of individuals is inferred by the choices they make. There are key conceptual differences between monetary valuation and alternative measures, although there is some evidence to show broad congruence between different types of value. For example, between the psychological well-being gains from experiencing the natural environment and people's assigned value of the same environment expressed through a choice experiment (Dallimer et al., 2013). Objections raised against the monetary valuation of nature argue that the full value of the natural world cannot be measured in monetary terms, or that if put into monetary terms the importance of nature might be diminished (e.g. Kahneman and Sugden, 2005; Spash and Vatn, 2006; Spangenberg and Settele, 2010). Indeed, economic valuation is unlikely to be appropriate for all types of environmental goods, especially when it comes to non-use values, such as existence value (Nunes and van den Bergh, 2001).

1.3. Thesis aims and objectives

Beyond the general introduction here, a further review of the topic specifically focusing on the role of biodiversity in human-nature interactions is given in **Chapter 2** placing this research into a broader context. Given the key knowledge gaps identified, this thesis specifically aims to:

(i) Identify specific characteristics of biodiversity that people perceive, value and gain benefit from.

(ii) Explore where win-wins and trade-offs may lie between human preferences, well-being and biodiversity conservation.

(iii) Take an interdisciplinary approach to studying human-biodiversity interactions, employing and combining methodologies from across natural and social sciences.

1.4. Thesis outline

A series of case studies from different study systems is used to investigate the specific characteristics of biodiversity that people perceive, prefer and gain benefits from. The thesis comprises of the following data chapters, each of which is a stand-alone research paper.

Chapter 2 assesses existing studies on human-biodiversity relationships in terms of individuals' perceptions, subjective well-being and objective measures of biodiversity. In doing so, a more complex and inconsistent relationship than is commonly assumed is discovered. A number of specific knowledge gaps are recognised, and these are further explored in subsequent chapters. A conceptual framework is developed and presented as a tool to unpack this complex relationship and the consequences of these findings for conservation are discussed.

Chapter 3 explores the complex socio-environmental conflicts surrounding the management of non-native invasive species, by employing a novel economic technique for studying people's relative preferences for different scenarios. A large sample from across three northern European countries is used and the extent to which preferences vary due to whether species are native, people's familiarity with species, perceptions of attractiveness and the type of management used is investigated.

Chapter 4 uses the study system of pollinator friendly experimental wildflower meadows, planted in urban greenspaces in UK cities, as a case study of a conservation intervention with potential to produce co-benefits for people. Taking an interdisciplinary approach, people's perceptions of the ecological characteristics of wildflower meadows are compared against objective measures obtained from biodiversity surveys. Alongside this, the extent to which these perceived and objective measures of biodiversity influence people's emotional and cognitive bond to the natural world are explored.

Chapter 5 employs the same econometric methodology from **Chapter 3** but applies it to public preferences for different characteristics of biodiversity from the wildflower meadows study system from **Chapter 4.** The extent to which greenspace users prefer, and were willing-to-pay, for changes to areas of greenspaces with regards to floral species richness, nativeness, appearance, and quality for pollinating insects is quantified. Further, variation in preferences between cities, and people's socio-demographic profile, is considered.

Chapter 6 explores a different, but complimentary, component of the human-nature relationships**,** by considering how access to greenspaces influences the level of physical activity of people in Kent, UK. Associations between the accessibility of greenspaces, as measured by government criteria, and physical activity of populations is investigated. The importance of sites varying in area, proximity and naturalness is examined, and implications for public health and landscape planning are discussed.

Chapter 7 brings these separate studies together and provides a discussion of the overall research undertaken and its contribution to a wider body of knowledge.

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Chapter 2. Unpacking the people-biodiversity paradox: A conceptual framework

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2.1. Abstract

Global phenomena, including urbanisation, agricultural intensification, and biotic homogenisation, 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 characterising 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.

2.2. Introduction

Despite considerable effort on the part of conservationists, the biodiversity (Table 2.1.) 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 behaviour (Fuller and Irvine, 2010, Duraiappah et al., 2013). However, the same global changes that threaten species and ecosystems, such as urbanisation, agricultural intensification, and biotic homogenisation, 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 wood- land), *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 greenspaces (e.g., public parks and woodlands, riparian areas, and private gardens; Table 2.1.) 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).

Table 2.1. 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 (CBD, 2015)
Greenspace	Open, undeveloped land with natural vegetation	Centers for Disease Control and Prevention (CDC, 2009)
Novel ecosystem	Ecosystems which 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

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 (Table 2.1.; 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 optimising access to urban greenspaces of high ecological 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).

2.3. How does biodiversity underpin human well-being?

Despite ecosystem assessments being the prominent lens through which nature is valued and incorporated into decision-making (MEA, 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 greenspace 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 greenspace 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 (Table 2.1.), 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 et al. (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 et al. (2012) found no consistent relationship between plant or butterfly species richness and self-reported psychological well-being within 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 et al. (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 greenspaces and related the presence of diversity to their well-being. At a neighbourhood scale, Luck et al. (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 et al. (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 greenspace studies highlighted above, people's predilections appear to be driven by the biodiversity they perceive to be present. However, there are exceptions. Qiu et al. (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 et al. (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 et al. (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 behaviour). 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 greenspaces (Lovell et al. 2014).

2.4. 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 eco-logical quality, incorporating a wealth of different aspects of human physiological, cognitive, emotional, social, and spiritual wellness, and studies have explored these facets 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 2.1.) 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 behaviours toward—biodiversity.

The type and intent of the human–biodiversity interaction is likely to influence the outcome (Church et al., 2014), which might be positive, neutral or negative (Figure 2.1.). 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 2.1., Table 2.2.). 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).

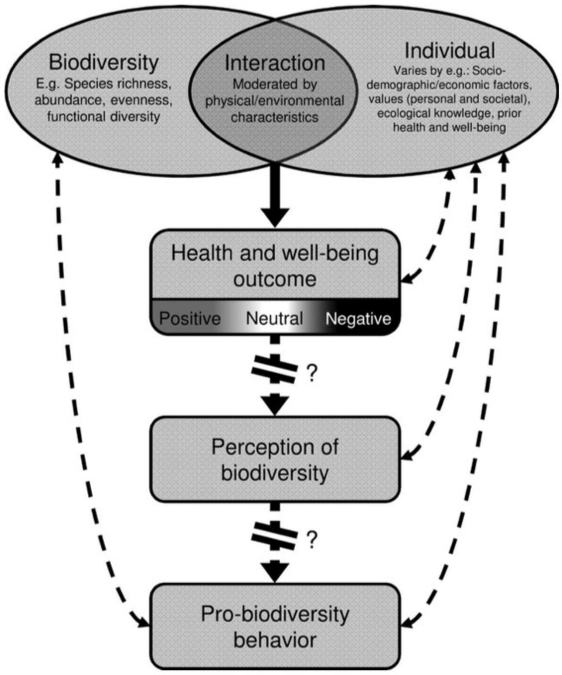

Figure 2.1. Conceptual framework of human–biodiversity interactions and potential outcomes for health and well-being, perceptions of biodiversity and pro-biodiversity behaviour. Human–biodiversity interactions can lead to a cascade of potential outcomes. The question marks represent less well-understood relationships. The dotted lines represent feedback from outcomes back to biodiversity or the individual.

Table 2.2. 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 greenspaces use greenspaces more regularly (Hillsdon et al., 2011).
Proximity	People with less greenspace 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 greenspace (Dallimer et al., 2014).

The outcome of an interaction with biodiversity can feed back to the individual (Figure 2.1.), 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 2.1., Table 2.3). To illustrate, a review of fear of crime experienced in urban greenspaces 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 et al., (2014) demonstrated that a cohort of Chinese people did not show a preference for biodiverse forest, whereas the comparative Swiss participants favoured species-rich forest over monoculture. Similarly, a study in Singapore found that neither access to nor use of greenspaces 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 greenspaces, if at all, can be influenced by both the characteristics of individuals (Table 2.3.), as well as the accessibility or proximity of the greenspace (Table 2.2.). 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 greenspaces than the availability of nearby greenspace (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 greenspace 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 et al., (2015b) suggested several potential dose–response relationships.

Table 2.3. 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 greenspace 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 greenspace 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 greenspace 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 neighbourhoods 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 favoured 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, greenspaces (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 neighbourhoods 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 greenspaces 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 greenspaces (Maruthaveeran and van den Bosch, 2014)
State of mind	Urban greenspaces which are perceived to contain more nature are also perceived to be more restorative by stressed individuals (Peschardt and Stigsdotter, 2013).

A further complexity that requires careful consideration is that spending time in greenspaces can be beneficial to individuals, not necessarily because of interaction with biodiversity but by virtue of the fact that it encourages and facilitates behaviours that are known to be mentally and physical favourable, 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).

2.5. 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 harbour many non-native 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 non-native species may possess traits (e.g., larger in body size, more colourful, or behaviourally 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 non-native species but who also need to encourage the health and well-being benefits that may be gained from interacting with charismatic non-native species. A better understanding of the public perception of non-native species could feed usefully into the ongoing debates on the legitimacy of the novel ecosystem (Table 2.1.) concept (Hobbs et al., 2009, Kowarik, 2011), as well as providing an evidence base for land-use planning, management, and decision-making.

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 behaviour. Indeed, positive attitudes toward biodiversity alone do not translate into pro-biodiversity behaviours (Figure 2.1.; 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 exposure to biodiversity and how this might, ultimately, lead to shifts in underlying attitudes and behaviour. 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.

2.6. Conclusion

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.

2.7. Acknowledgements

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Chapter 3. Who's a pretty parrot: Public preferences for native and non-native invasive bird species

Submitted after revisions to *Ecological Applications*

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3.1. Abstract

Invasive species are a significant driver of biodiversity declines and can be responsible for a variety of negative socioeconomic impacts. The financial costs associated with the environmental and economic mitigation of invasive species can be substantial, and policy responses operate at multiple scales to combat the problem. However, despite being key to effective policy implementation, we have little understanding of public preferences (both positive and negative) for invasive species and their control. Here we use a choice experiment to quantify willingness-to-pay (WTP) for, or willingness-to-accept (WTA), future changes in population size of invasive and native birds, and the type of management used. The survey design examined how species' attractiveness, and whether respondents had been exposed to it, modifies findings. Hypothesising that preferences are likely to vary across countries, even with similar avifaunas, we administered our survey across over 3000 people in the UK, Germany and The Netherlands. We found no variation between respondents living in different countries. Nevertheless, there was substantial heterogeneity. Despite being aware that the species were pests, the public prefer to maintain the status quo and do not wish to see large population declines. People had a WTA for a small increase in population sizes, but were ambivalent about a small decrease. The strongest preference was to avoid lethal control measures. Crucially, the public are not concerned with the concept of nativeness. Further, management responses to invasive species need to be cognisant of how attractive a particular species is deemed to be. Policies need to facilitate the rapid implementation of interventions to control an invasive bird, because people who are yet to be exposed to the species are more likely to countenance population size management. If a non-native species becomes invasive, and its distribution expands, more people will encounter it and become resistant to actions to reduce populations.

3.2. Introduction

Invasive species are a significant driver of biodiversity declines and extinctions (Simberloff et al., 2013; Bellard et al., 2016). Additionally, they can be responsible for a variety of negative socioeconomic impacts (e.g. cause damage to built infrastructure) and unduly influence ecosystem services fundamental to human wellbeing (Binimelis et al., 2007). Defined as non-native species whose introduction or spread threatens or adversely impacts biodiversity (EU, 2014), the financial costs associated with the environmental and economic mitigation and control of invasive species can be substantial. For example, the average annual expenditure for just 20 invasive species in Germany has been estimated to be €167 million (Reinhardt et al., 2003). Similarly, invasive species are thought to cost the British economy £1.7 billion per year (Williams et al., 2010). Policy responses have been developed at multiple scales to combat the problem. Internationally, both the Convention on Biological Diversity Strategic Plan for Biodiversity (SCBD, 2010) and the Sustainable Development Goals (SDGs, 2015) call for measures to prevent the introduction, and reduce the negative impacts, of invasive species. European Union legislation also requires Member States to take concerted efforts to prevent the spread and introduction of invasive species (EU, 2014). Nationally, examples include policy in Australia that focuses on biosecurity to prevent new introductions (DAFF, 2012), and the New Zealand government's intention to eradicate all invasive predators by 2050 (Department of Conservation, 2017). Consequently, interventions to manage invasive species populations are becoming increasingly widespread, and are no longer just restricted to small islands (e.g. IUCN, 2016). Nonetheless, non-native and invasive species continue accumulate globally, with introductions driven by the growth in trade and human travel (Dyer et al., 2017; Seebens et al., 2017).

As humans play an integral role in the release, establishment and spread of invasive species, it is important to understand people's perceptions of their management and population sizes to implement effective and socially acceptable policy responses. Yet, people's values and attitudes towards non-native and invasive species are poorly understood (Russell and Blackburn, 2017). In some cases, invasive species cause measurable decreases in life satisfaction (Jones 2017), due to factors such as disease transmission and noise disturbance (Kumschick and Nentwig, 2010). However, with the human population becoming progressively more urban (UN, 2015), and biotic homogenisation occurring within towns and cities across the world, non-native species are often those that the public interact with on a regular basis (McKinney, 2002). For instance, grey squirrels in the UK and Eurasian blackbirds in New Zealand are ubiquitous in urban parks and gardens, where they have largely replaced their native equivalents. It is probable that the public may prefer species that they have been exposed to and are familiar with. Therefore, as species are not evenly distributed, the values associated with them may alter spatially. Different preferences for species and types of management may also reflect cultural attitudes towards nature (e.g. Ressurreição et al., 2012; Lindemann-Matthies et al., 2014; Dallimer et al., 2014; Crowley et al., 2017; Tassin et al., 2017). Indeed, we still know very little about the role such species play in the provision of cultural ecosystem services (the non-material benefits that people obtain from ecosystems, including recreation and aesthetic appreciation; MEA, 2005) (Pejchar and Mooney, 2009). Moreover, there is a rapidly growing body of literature demonstrating the personal and societal health and wellbeing benefits people derive from experiencing nature (Keniger et al., 2013), although there is a paucity of more nuanced evidence regarding how particular components of biodiversity may contribute to the phenomenon (Pett et al., 2016).

Scientific thinking regarding the legitimacy of novel ecosystems (e.g. Hobbs et al., 2009; Murcia et al., 2014), defined as “human-built, modified niches that exist in places that have been altered in structure and function by humans”, and the degree to which non-native species should be managed has been hotly debated (e.g. Davis et al., 2011; Richardson and Ricciardi, 2013; Thomas, 2013; Thomas and Palmer, 2015; Crowley et al., 2017; Davis and Chew, 2017; Russell and Blackburn, 2017; Tassin et al., 2017). However, the public relate very differently to the ecological concept of nativeness and find it less relevant to their perceptions of species (Selge and Fischer, 2010). This is exemplified by the fact that people are less inclined to support the control of non-native plants and animals that they find appealing (Bremner and Park, 2007; Verbrugge et al., 2013; Lindemann-Matthies, 2016; Vane and Runhaar, 2016), and the attractiveness of species can vary according to their shape and colour (Stokes, 2007; Lišková and Frynta, 2013; Lišková et al., 2015). Successful implementation of invasive species management policies will thus require meaningful public engagement (Santo et al., 2015; Crowley et al., 2017). Opposition, non-compliance and conflict associated with the eradication and control of species can increase costs, delay action and ultimately cause failure in outcomes (Estévez et al., 2015).

Here we tease apart some of these complexities by examining whether or not: (i) preferences for species population sizes and management vary between countries; (ii) values differ if species are native or invasive; (iii) the extent to which species preferences may be related to exposure; and, (iv) visual attractiveness can influence values. We do this using birds as our focal taxonomic group, as they are a highly visible component of nature, and the one that people are often most familiar with (Dallimer et al., 2012; Belaire et al., 2015). Indeed, there is a growing literature that shows that people place an economic value on viewing birds and efforts to conserve birds (e.g. Clucas et al., 2015; Czajkowski et al., 2014; Loomis et al., 2018). We conduct our study across three countries in northwest Europe: UK, Germany and The Netherlands. These nations were selected because they have the same policy framework (EU, 2014) and share a similar avifauna. Although many policies pertaining to invasive species are mandated at a supranational level, they are often implemented at national or sub-national scales (Tollington et al., 2015). Additionally, by their very definition, invasive species are characterised by an expanding distribution. As such, their control can require collaboration across socio-political boundaries. It is important to consider potential differences between public perceptions in different countries, as cooperation is only likely to be successful if the outcomes are mutually desirable to all parties (Dallimer and Strange, 2015).

3.3. Methodology

To investigate people's preferences for native and invasive bird species, and their management, we used a discrete choice experiment, which is a stated preference non-market valuation technique often used to inform environmental decision-making processes (Hanley and Barbier, 2009). For example, choice experiments have been used to estimate preferences for conserving birds immigrating due to climate change (Lundhede et al., 2014) or to quantify how the people's values for conserving species rich grassland vary across multiple countries (Dallimer et al., 2014). This study is the first to use to the method to specifically value preferences for both native and invasive species.

When conducting a choice experiment, respondents pick their preferred option from a set of alternative 'goods' which. Lancaster (1966) showed that any good can be viewed as a bundle of characteristics or 'attributes', and that people will choose the good with the attributes that offer them the highest utility (i.e. satisfy their needs or wants). By applying Random Utility Theory (McFadden, 1980), we are able to estimate people's relative preferences for each attribute. This is achieved by making people express their preferences through trade-offs, allowing us to calculate the marginal utility for individual attributes, which may otherwise only be considered in aggregate (Adamowicz et al., 1998). By including a monetary cost in the choices, a 'willingness-to-pay' (WTP) metric for each attribute can be derived. 'Willingness-to-accept' (WTA) is the inverse of this, representing disutility or the amount of compensation that a respondent would hypothetically need to be satisfied with an undesirable situation.

3.3.1. Study system and questionnaire design

We held a series of focus groups to investigate knowledge of, and attitudes towards, invasive and native species among members of the public. We trialled a range of terminology such as 'non-native', 'introduced', 'alien' and 'invasive' to gauge people's understanding of these phrases and how they relate to bird species. We chose to use the framing of 'invasive' and 'native' species, as the terms are used in the scientific and policy literature, as well as being understood by the vast majority of focus group participants.

We chose three invasive birds found across the UK, Germany and The Netherlands that varied in their colourfulness, relative abundance and range (Table 3.1.). The house crow (*Corvus splendens*) was picked for inclusion due to the species being at beginning of the invasion process, having a small population in The Netherlands (BirdLife International, 2017) and expected to arrive in the UK imminently (Marchant, 2012). The species is morphologically similar to, and could be mistaken for, a native crow or jackdaw. Canada geese have been long established in all three study countries and their populations have increased with changing agricultural practises and urban expansion (DAISIE, 2007b). They are well known to the public as they form large flocks and are often associated with urban parks. Finally, we specifically focused on the ring-necked parakeet (*Psittacula krameri*) because it is strikingly different in appearance compared to the native avifauna and, anecdotally, polarises public opinion (Barkham, 2009). This was confirmed within the focus groups.

Table 3.1. Name, illustration, distribution, impacts and current management status of the six bird pests used in a choice experiment, conducted across the UK, Germany and The Netherlands, to determine public preferences for the population size and management of native and invasive species.

Common name (*Latin name*), illustration and status	**Distribution in study countries**	**Impacts**	**Management**
Ring-necked parakeet (*Psittacula krameria*)  Invasive	Established populations in the UK, Germany and The Netherlands (BirdLife International, 2017), increasing in population size and distribution across Western Europe (DAISIE, 2007a).	Some evidence of competition for nest holes with native birds such as *Sitta europea* (Strubbe and Matthysen, 2009). Known agricultural pest, for example damaging fruit trees in the UK (Marchant, 2016). Potential for noise disturbance has been highlighted in reviews and reports (e.g. DAISIE, 2007a), and potential risk to human health associated with fouling near large roosts (Marchant, 2016).	Currently no active widespread prevention or mitigation management taking place. Mechanical trapping has been used to remove individuals in an introduced population in Australia (DAISIE, 2007a).
Woodpigeon (*Columba palumbus*)  Native	Native resident populations in the UK, Germany and The Netherlands (BirdLife International, 2017). The population size has increased moderately in Europe since 1980 due to their ability to exploit human-modified habitats (EBCC, 2015).	Recognised as an agricultural pest due to feeding on a range of arable crops, with the problem considered to be growing (Parrott et al. 2014). The increase in numbers in urban areas leads to them being perceived as pests by some people as they scare other birds from feeding tables (e.g. Wild About Gardens, 2013).	Scaring (e.g. gas canons) and exclusion (e.g. nets) techniques are used to mitigate damage to crops. Shooting adult birds is also used as a deterrent and to control numbers (Parrott et al., 2014).

Common name (*Latin name*), illustration and status	**Distribution in study countries**	**Impacts**	**Management**
House crow (*Corvus splendens*)  Invasive	Confirmed self-sustaining population recorded in coastal areas in The Netherlands (BirdLife International, 2017; Marchant, 2012), and unconfirmed reports of sightings of individuals in the UK (Ryall, 2016). The GB non-native species secretariat lists the species as expected to arrive in Great Britain (Marchant, 2012). Ecological niche models suggest suitable conditions for the species to expand in Europe (Nyári et al., 2006).	Reported to have impacts on native bird species through nest predation (Ryall, 1992a), as well as causing damage to arable crops and poultry (Global Invasive Species Database, 2017). The species has been noted as a potential vector of human pathogens as it feeds on waste close to human habitation (Ryall, 1992b). Perceived as a nuisance and presents a threat to tourism in some regions (Global Invasive Species Database, 2017).	Following a risk assessment (Slaterus et al., 2009), the government of The Netherlands started an eradication programme in 2012. A few individuals are thought to persist (Ryall, 2016). Managed by shooting and destruction of nests (CABI, 2017).
Carrion crow (*Corvus corone*)  Native	Native resident populations in the UK, Germany and The Netherlands. Moderate increase in population size in Europe since 1980 (EBCC, 2015). Live in higher densities in urban habitats (Sorace, 2002).	Considered a pest due to noise and high abundance in urban areas (Sorace, 2002). Agricultural pest, causing damage to arable crops (Heynen, 2004).	Managed via shooting outside of the breeding period, cage trapping, and cervical dislocation (Baker et al., 2016). Deterred using various scaring techniques (e.g. gas canons, balloons, scarecrows) (Baker et al., 2016; Haynen, 2004)

Common name (*Latin name*), illustration and status	**Distribution in study countries**	**Impacts**	**Management**
Canada goose (*Branta canadensis*)  Invasive	Established populations in the UK, Germany and The Netherlands (BirdLife International, 2017), and increasing in population size in northern and western European countries (DAISIE, 2007b).	Droppings can lead to eutrophication of still waters (Watola et al., 1996) and are a potential hazard to public health (NOBANIS, 2008). Damages arable crops and natural shoreline vegetation by heavy grazing and trampling (NOBANIS, 2008). Can damage aircraft through air strikes (NOBANIS, 2008).	Shooting and scaring techniques are used to discourage geese on farmland and near airports. However, this does not reduce population sizes (NOBANIS, 2008). Prevention of hatching by manipulating eggs is practised in the UK (CABI, 2017).
Greylag goose (*Anser anser*)  Native	Native resident populations in the UK, Germany and The Netherlands. Estimated to be increasing in population size in Europe (BirdLife International, 2017).	Environmental impact on vegetation dynamics in salt marshes due to feeding behaviour (Esselink et al., 1997). Intense localised damage to arable crops and grass (Boere et al., 2006).	Farmers cull by shooting to protect crop locally, but it is not systematic (Boere et al., 2006). A range of scaring techniques (e.g. gas canons, scarecrows) are used (Boere et al., 2006).

In general, we expected people to view the management of bird species to control population size as undesirable. Previous research has found that people's support for control or eradication programmes involving birds is significantly less than for other taxonomic groups, and many commonly used control methods are deemed objectionable (Bremner and Park, 2007). Again, this was verified during focus groups.

Given that management is central to the control of invasive species population sizes when and where they are causing negative social or environmental impacts, we included native species in the questionnaire that are also subject to comparable interventions. We did this by including native birds that are sometimes considered pests, all of which can be managed to reduce their abundance as a damage mitigation strategy, in our choice experiment design (Table 3.1.). We matched pairs of native and invasive birds ensuring that, where possible, they were broadly visually and morphologically similar. A native, morphologically similar substitute for the ring-necked parakeet does not occur in the study region. Following discussions in the focus groups, we paired the ring-necked parakeet with the woodpigeon, which is another well-known and similarly sized pest species.

Previous studies have shown that providing the names of species can affect valuation estimates (Jacobsen et al., 2008). The choice sets in our questionnaire included an illustration of each the bird species and its Latin name. We avoided common names so that, as far as possible, respondent's preferences would be based on prior experiences of the species, its visual appearance, and the information we provided in the questionnaire. Illustrations from the same source were used to ensure a level of consistency between images.

The focus groups suggested that the method of control was a particularly important attribute of pest species management and, therefore, we tested this in our choice experiment. The attributes integrated into the questionnaire were bird species population size change (described as the change from what the population is predicted to be in 10 years time) and control method (Supporting Information Appendix S3.8.1.) payment vehicle was described as an annual income tax increase attribute for the respondent's household. This cost was given in the local currency of each country, converted using Purchasing Power Parity (PPP) (World Bank 2015).

Each set of choices consisted of three options, one of which was always 'no change', both in relation to the cost and management (Supporting Information Appendix S3.8.2.). Questionnaire pre-testing helped to refine the wording of questions, costs and choice set designs. The questionnaire was piloted online (n=106) and further adjustments were made in response to the feedback received and results of preliminary analyses, principally with regard to the description of different attribute levels.

We created an efficient choice experiment design using Ngene (version 1.1.2; 2014) consisting of 24 choice sets (Supporting Information Appendix S2), using parameter values determined from the results of our pilot questionnaire. The ex-post d-error for the final multinomial model was 0.000258, which is acceptable (see e.g. Scarpa and Rose 2008). As completing a large number of choices is cognitively demanding (Weller et al., 2014), we divided the design into two blocks so that each respondent only had to complete one block of 12 choice sets. To investigate whether knowing the status of a species influences attribute preferences (Selge et al., 2011; Sharp et al., 2011), we also split the survey so that only half of the respondents were told whether each species was native or invasive (Supporting Information Appendix S3.8.2.). Consequently, four questionnaire variants were distributed in each country. The questionnaire was professionally translated from English into German and Dutch, with the translations piloted by bilingual speakers to ensure consistency between the versions in different languages.

3.3.2. Data collection

Questionnaires were hosted on Bristol Online Survey (BOS 2016) and distributed online between February and March 2016. A commercial polling company was used to recruit respondents to ensure that the socio-demographic/economic background of our sample in each country was representative of the wider population as possible. Approximately 3,000 individuals were invited to take part in the study in each country, evenly allocated between the four questionnaire variants. We sampled in cities with either a high or low occurrence of ring-necked parakeets, so we could assess any potential relationship between people's preferences and the prevalence of the species. We identified suitable urban areas using population and distribution maps from the European Monitoring Centre for non-native parrot species (ParrotNet, 2016). Data collection was considered to be complete when a minimum of 250 respondents had completed each of the four questionnaire variants in each of the three countries. Respondents were asked to provide informed consent before starting the questionnaire, being made aware that their participation in the research was entirely voluntary, they could stop at any point and withdraw from the process, and that their answers would be anonymous and unidentifiable. All respondents were aged 18 years or over. Ethics approval was granted by the relevant Research Ethics Committee for the authors' institution prior to launching the questionnaire.

3.3.3. Data analysis

Before beginning our analyses, we removed data associated with six respondents who did not record answers to all their questionnaire choice sets. Additionally, we corrected the sample for serial non-participation, by excluding a further 123 respondents (3.9%) who chose the ‘no change’ option for all choice sets and whose answers to a follow-up question indicated that they were protesting against the questionnaire or the payment vehicle (von Haefen et al., 2005) (Supporting Information Appendix S3.8.3.).

A random parameter model was constructed using NLOGIT (version 4.0; 2007), which allowed us to model possible heterogeneity in preferences by assuming a probability distribution around the estimated preference parameters (McFadden and Train, 2000) (Supporting Information Appendix S3.8.4.). Standard errors around the WTP/WTA estimates were calculated using the Delta-method (Greene, 2000). A scale parameter is embedded in the preference parameter, which normally prevents comparison of preference parameters across different groups of respondents. In this choice experiment, these groups are the three countries. When calculating WTP/WTA, the scale parameter forms part of both nominator and denominator, thus cancelling itself out and allowing comparisons to be made across groups (Hensher et al., 2015). An alternative approach is to correct for scale when estimating the preference parameters. As both methods generated comparable results, we only present the former. All preference parameter estimates should be interpreted as the magnitude of utility/disutility associated with a shift in attribute levels relative to the Alternative Specific Constants (ASC), the parameter representing the ‘no change options’. These no change options are also referred to as the status quo in the economic literature. Finally, to determine whether preferences varied because of bird species characteristics, such as their appearance, we estimate the marginal utility for interactions between specific species and attribute levels (i.e. the additional or reduced WTP for a small decrease in population of ring-necked parakeets compared to the other bird species). Figures were generated in QGIS (2017), R (2016) or Datagraph (2017).

3.4. Results

A total of 3,131 respondents completed the questionnaire. After the incomplete and serial non-participation data were excluded, we had a final sample of 3,008 respondents (N) and 36,096 completed choice sets (Supporting Information Appendix Table S3.8.5.1.). Overall, 41% (n=1,230) of respondents were from cities that are known to have high numbers of ring-necked parakeets (Figure 3.1.). Of these, 56% (n=693; 23% of N) stated that they had seen the species in the area where they live, after they were presented with an illustration and the Latin species name. Only 10% (6% of N) of respondents living in areas without a recorded breeding population of ring-necked parakeets reported seeing the species locally. Therefore, in subsequent analyses, we use the people's response to the question 'Have you ever seen this species in the town/city where you live?' to distinguish between individuals who had and had not been exposed to ring-necked parakeets.

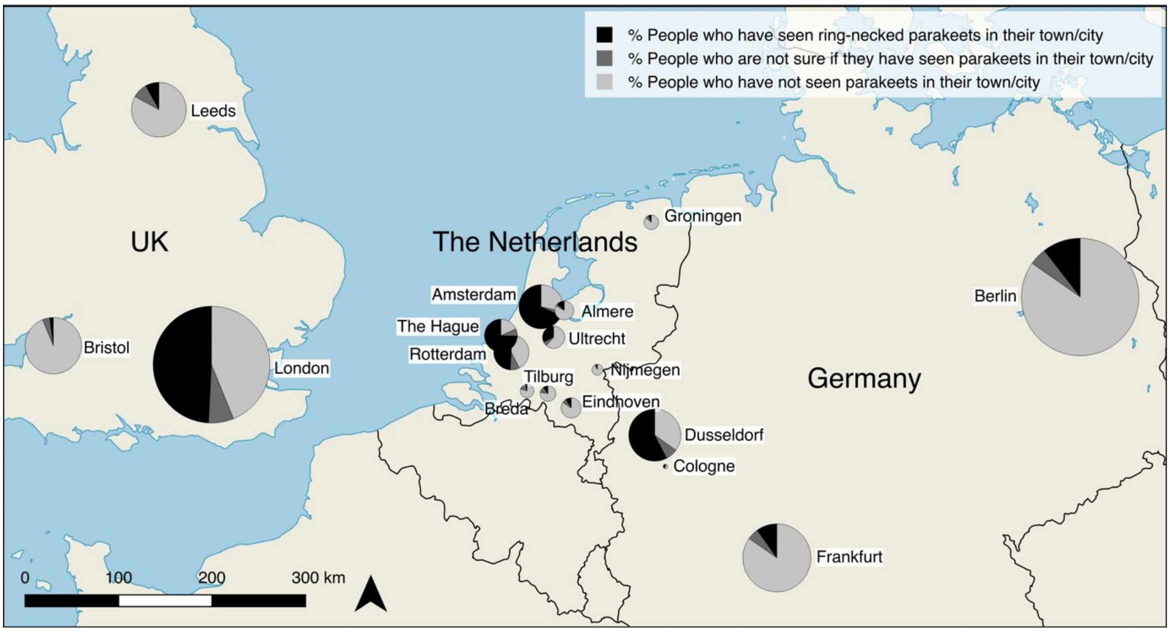

Figure 3.1. Northwest Europe showing the location of the study cities within the UK, Germany, and The Netherlands where a choice experiment was conducted to determine public preferences for the population size and management of native and invasive bird pest species. The pie chart associated with each city indicates the percentage of respondents who have seen ring-necked parakeets locally. The diameter of the pie charts is proportional to the respondent sample size in each city.

In a full model, comprising all bird species and respondents from across the three study countries, the cost attribute estimate was significant and negative, demonstrating that people view an increase in tax as a disutility, which is to be expected. All other attributes were estimated as random parameters, assumed to be normally distributed and all simulations were based on 1,000 Halton draws (Train, 2009). Their standard deviations were significant, indicating that preferences for the attributes are heterogeneous. Only the deterrent option for controlling population sizes had no significant effect on choice (Table 3.2.). There was a substantial and significant WTP for the no change option (ASC), indicating that respondents would prefer keep things as they are currently, rather than altering current management or future projected bird species population sizes. However, they also expressed a significant WTP for a small decrease in population sizes. People had a significant disutility (i.e. a WTA not WTP) for the lethal control and no management options. Likewise, there was a significant disutility for a small increase or large decrease in population sizes.

Table 3.2. Parameter estimates and willingness-to-pay (WTP) or willingness-to-accept (WTA), showing people's preferences for the population size and management of native and invasive bird pest species, from a random parameter logit model. WTP/WTA is presented in £GB per household per year. The model is derived from 36,096 choices made by 3,008 respondents (χ^2=16,826.65, pseudo-R^2=0.212, log-likelihood=-31,242.18). Stars indicate significance: **p≤0.01.

Attribute (and levels for control and population)		**Parameter Estimate**			**Standard deviation**			**Willingness-to-pay/accept**		
		Value		**SE**	**Value**		**SE**	**Value**		**SE**
No change options (ASC)		0.755	**	0.043				WTP 8.52	**	0.625
Control	Lethal	-0.941	**	0.053	1.248	**	0.056	WTA 10.61	**	0.643
	Deterrents	-0.048		0.041	1.138	**	0.038	WTA 0.54		0.459
	No management	-0.138	**	0.042	1.126	**	0.041	WTA 1.55	**	0.474
Population	Small decrease	0.140	**	0.039	0.892	**	0.037	WTP 1.58	**	0.445
	Large decrease	-0.198	**	0.046	1.200	**	0.043	WTA 2.23	**	0.514
	Small increase	-0.503	**	0.046	1.187	**	0.044	WTA 5.67	**	0.521
Cost		-0.089	**	0.003						

There were no statistically significant differences (p always >0.10) in the WTP estimates for each attribute between respondents from the UK, Germany and The Netherlands. All subsequent analyses were, therefore, carried out using the data from the three countries combined.

Table 3.3. Parameter estimates and willingness to pay (WTP) or willingness to accept (WTA) of people's preferences towards population size and management options to control native and invasive bird species. From a random parameter logit model with main attributes of control and population, based on the full sample of 36,096 observations from 3,008 respondents (χ^2 = 16,826.65, pseudo-R^2 = 0.212, log-likelihood = -31,242.18). * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

Variable		Parameter			Standard deviation			Willingness to pay		
		Value		SE	Value		SE	Value (in £)		SE
No change options (ASC)		0.755	***	0.043				8.515	***	0.625
Control	Lethal	-0.941	***	0.053	1.248	***	0.056	-10.610	***	0.643
	Deterrents	-0.048		0.041	1.138	***	0.038	-0.540		0.459
	Removal of management	-0.138	***	0.042	1.126	***	0.041	-1.551	***	0.474
Population	Small decrease	0.140	***	0.039	0.892	***	0.037	1.577	***	0.445
	Large decrease	-0.198	***	0.046	1.200	***	0.043	-2.233	***	0.514
	Small increase	-0.503	***	0.046	1.187	***	0.044	-5.665	***	0.521
Cost		-0.089	***	0.003						

3.4.1. The effect of nativeness and stated species nativeness

Respondents had a significantly higher WTP for the no change option for invasive species than they did for the native species (Figure 3.2.; Supporting Information Appendix Table S3.8.5.3.). Consistent with the full model, people had a significant disutility for the use of lethal bird management across all survey splits. Additionally, respondents had a significant disutility for the control of bird pests using deterrents for invasive birds, but no such trend was found for native species, regardless of whether the species was stated as being native/invasive in the choice set.

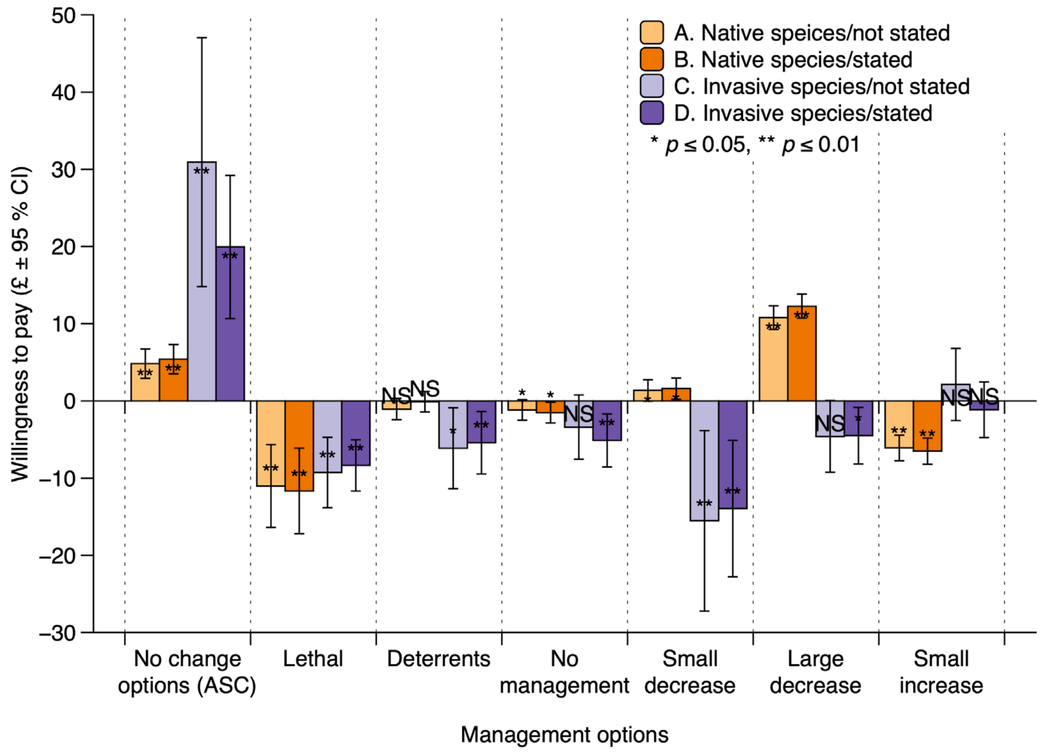

Figure 3.2. People's willingness-to-pay (WTP) or willingness-to-accept (WTA) changes in population size and management options to control native and invasive bird pest species (Supporting Information). WTP/WTA is presented in £GB per household per year. WTA is negative WTP. The WTP/WTA were calculated from four random parameter logit models, split by whether species were native or invasive, and whether species were stated as being native/invasive in the choice set. Error bars show 95% confidence intervals.

Respondent's preferences for small or large decreases in population size were a significant WTP for native birds. Conversely, preferences for a small increase in population size were a significant WTA for native species. For invasive species, preferences were a significant disutility for small population size decreases, regardless of whether or not the species was classified as being native/invasive (Figure 3.2.; Supporting Information Appendix Table S3.8.5.3.). This became not significant for large population size decreases for invasive species that were not stated as being invasive in the choice set.

3.4.2. Effect of exposure to ring-necked parakeets

People's preferences for lethal control were not significantly different for ring-necked parakeets compared to other species, irrespective of whether they had seen the parakeets in their city or not (Figure 3.3.; Supporting Information Appendix Table S3.8.5.4.). Respondents who have been exposed to ring-necked parakeets had a significantly higher marginal WTP for the use of deterrents to manage ring-necked parakeets compared to other birds. Regardless of whether or not respondents had encountered ring-necked parakeets in their city, people had a significantly lower marginal WTA for no management to control parakeets than for the other five bird species.

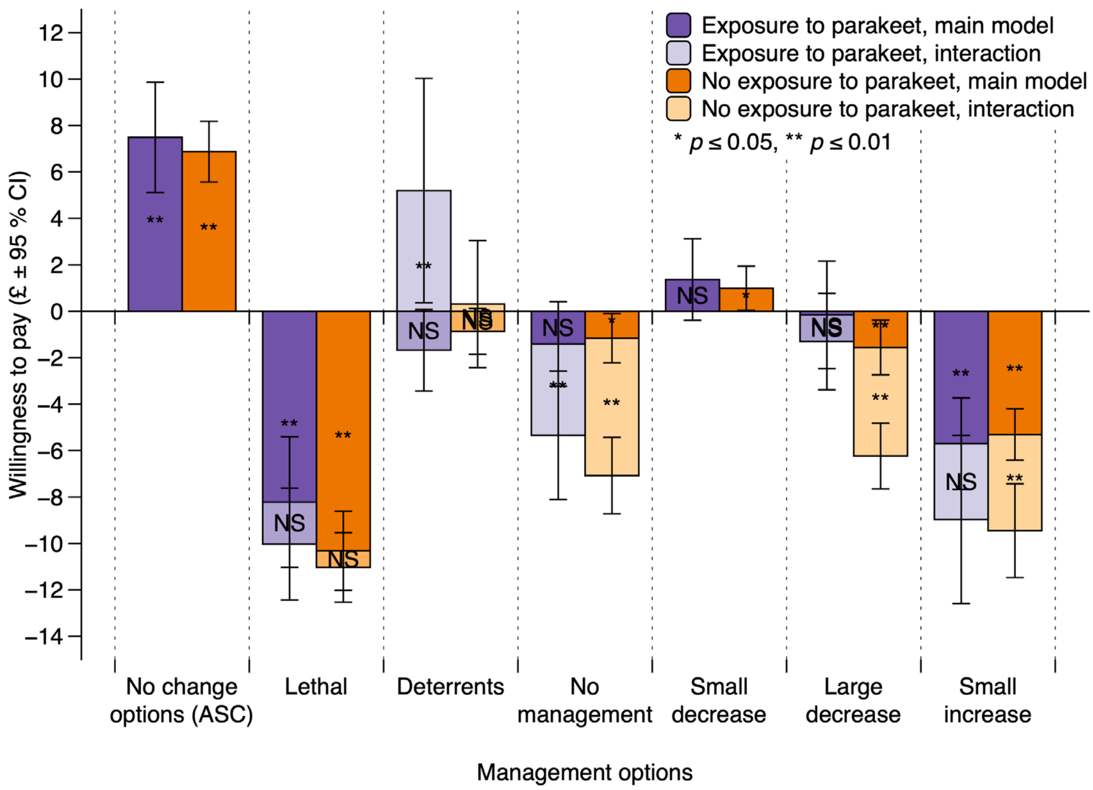

Figure 3.3. People's willingness-to-pay (WTP) or willingness-to-accept (WTA) changes in population size and management options to control native and invasive bird pest species (Supporting Information). WTP/WTA is presented in £GB per household per year. WTA is negative WTP. The WTP/WTA were calculated from two random parameter logit models, split by whether respondents have seen ring-necked parakeets in the city they live in (so have been exposed to them) or not. Error bars show 95% confidence intervals. Please note, the interaction term associated with ring-necked parakeets and a small decrease in population size could not be estimated within the choice experiment design.

We found no preference for a large decrease in the population size of ring-necked parakeets for respondents who have seen them in their city. However, there was a significant marginal disutility for the same shift in population size for those who had not been exposed to the ring-necked parakeet. People who have not seen ring-necked parakeets had a significantly lower marginal WTA for a small increase in parakeet population size compared to the other bird species. In comparison, this is not the case for respondents who have been exposed to ring-necked parakeets.

3.4.3. The effect of bird attractiveness

Invasive species were consistently ranked as more attractive than their paired native species, and the ring-necked parakeet was rated as the most attractive bird by 60% of respondents (Supporting Information Figure S3.8.5.5.). Respondents who ranked the ring-necked parakeet as the most attractive bird did not have a significant marginal disutility for the use of lethal control to management ring-necked parakeet populations in contrast to other birds (Figure 3.4.; Supporting Information Appendix Table S3.8.5.6.). However, a significant and lower marginal WTA for the use of lethal control was apparent for people who did not rank the ring-necked parakeet as the most attractive species. Similarly, this cohort of respondents had a significant marginal WTP for the use of deterrents to control population sizes, whereas those who thought the ring-necked parakeet was the most attractive bird did not. Both groups of respondents had a significant marginal WTA for no management to control ring-necked parakeets than for the other five species.

People who ranked the ring-necked parakeet as the most attractive bird had a significantly greater marginal disutility for large population size decreases, whereas this was not the case for those individuals who did not favour the species. Both those who preferred the ring-necked parakeet and those who did not had a significant marginal WTA for a small increase in parakeet population size.

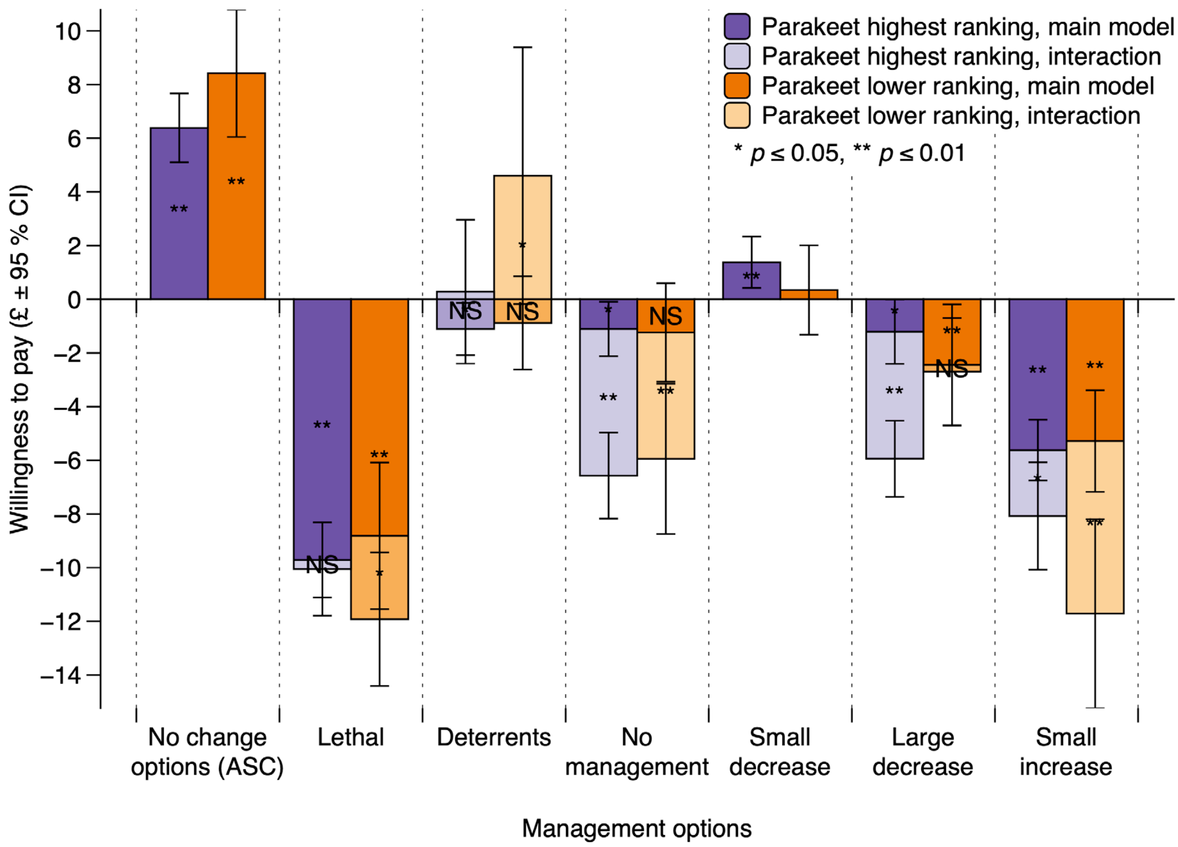

Figure 3.4. People's willingness-to-pay (WTP) or willingness-to-accept (WTA) changes in population size and management options to control native and invasive bird pest species (Supporting Information). WTP/WTA is presented in £GB per household per year. WTA is negative WTP. The WTP/WTA were calculated from two random parameter logit models, split by whether respondents rank the rick-necked parakeet at the most attractive bird or not. Error bars show 95% confidence intervals. Please note, the interaction term associated with ring-necked parakeets and a small decrease in population size could not be estimated within the choice experiment design.

3.4.4. Stated reasons for choices

When making their choices, respondents most commonly stated (59%) that they always paid attention to the bird species (Supporting Information Figure S3.8.5.7.). In contrast, the least important consideration was whether the species was native or invasive. Nevertheless, 27% of respondents who were not given the native/invasive classifications stated that they considered whether or not the species was invasive when choosing between options in the choice sets. Finally, across the entire sample, 48% of people said that they had previously heard the term 'invasive species' and were aware of its definition, with 44% understanding that term refers to species that 'do not occur naturally in their country' (i.e. are non-native).

3.5. Discussion

Understanding the factors influencing people's preferences for different species and the types of management that could be used to control their future population sizes, is key to developing and implementing effective invasive species policies. One clear finding is that members of the public in the UK, Germany and The Netherlands had a WTP (utility) for maintaining the status quo for the birds in our study and expressed a disutility for large population size declines. However, they are also aware that the birds were pests. As such, people wanted to be compensated for a small increase in population sizes, but were more ambivalent about a small decrease. The strongest preference was to avoid additional lethal control measures for the six bird species.

When we examined whether or not there were any differences between native and invasive species, we found that the public had a significantly greater WTP for the no change option, in regard to both management and populations sizes, for the invasive birds. There were also disparities between preferences related specifically to changes in future population size. People had a WTA for invasive species population decreases, yet a WTP for the same in native species. Additionally, they had a WTA for small increases in native bird population sizes, which was not the case for invasive species. These trends remained the same, irrespective of whether the species in each choice set were classified as native/invasive or not. This is unsurprising to some extent, as less than a third of respondents stated that they always considered the status of the bird when making their choices, and approximately half of respondents were not aware of what the term 'invasive species' meant, despite it being the preferred term during our focus groups. Indeed, Lindemann-Matthies (2016) reported comparable findings for invasive plant species in Switzerland. Yet, contrary to our findings, Yue et al. (2011) found that people have a higher WTP for ornamental plants that were labelled as native rather than invasive. Several studies have also shown that the UK public have a limited knowledge of local plants and animals (e.g. Pilgrim et al., 2008; Dallimer et al., 2012) and, therefore, are unlikely to know the status of the six bird species. Moreover, our results may additionally reflect the fact that the public do not perceive species that originate from another country as being particularly problematic and, consequently, this is unlikely to inform their attitudes towards management (van der Wal et al., 2015). For example, a recent EU-wide survey found that 'introduced non-native plants and animals' were considered to be less of a threat than pollution, man-made disasters, climate change, overexploitation, land-use change and habitat fragmentation (EC, 2015).

The results described above indicate that other factors shape people's preferences for the future population sizes and management of bird species. First, we explored how having been exposed to a species could be important, using the ring-necked parakeet specifically. In theory, a continuum of outcomes might be experienced, from severe negative impacts (e.g. damage to infrastructure, interspecific competition with native species, noise disturbance; DAISIE, 2007a; Fletcher and Askew, 2007; Marchant, 2016), through to positive interactions (e.g. enjoying seeing/feeding individuals; Braun and Wegener, 2008; Wolff and Touratier, 2010). As Warren (2007, p.431) states “one person’s pest is often another’s livelihood or joy”. Our findings indicate that members of the public would want more compensation for no management to control ring-necked parakeets, relative to the other five birds, regardless of whether or not they had seen them in their city. Additionally, people who had been exposed to ring-necked parakeets had a substantial WTP for the use of deterrents to scare away parakeets, compared to other pest species. This could be because they are familiar with the problems that the species may cause, so are willing to take action, akin to a not-in-my-backyard (NIMBY) attitude where people do not want an issue/item near to where they live (Young, 1993; for a biodiversity valuation example see Ericsson, et al. 2008). Nonetheless, this did not influence their opinion on changes in ring-neck parakeet population sizes specifically, relative to the other bird species; they viewed the parakeet no differently to the other pests. Contrary to this, respondents who had not seen the parakeet were notably less tolerant of this particular species, having a significantly larger WTA for an increase in population size or the withdrawal of management. The impact of individuals’ experiences on values for environmental goods is increasingly receiving attention in the economic valuation literature. Previous studies have found higher WTP values for users vs. non-users of environmental goods, when familiarity is defined as previous use of the good (Choi, 2013; Jørgensen, et al. 2013). Similarly, others have found WTP for a resource to increase with experience, measured as the number of years a respondent used a good (Cameron and Englin, 1997). Taking a more sophisticated approach to defining familiarity and experience, a study on public preferences towards the expansion of a port found differences in respondents’ WTA compensation depending on previous use, number of years they had lived near the port, and physical proximity (Tabi and del Saz-Salazar 2015). In comparing our findings to this literature, a common finding is that the valuation of non-market goods is influenced by respondent’s personal involvement with these goods and therefore, a more nuanced view of the variation in people’s preferences is required. The symbolic meanings assigned to species add further complexity to how the same species can be viewed differently by different stakeholders. For example, a social conflict between farmers and members of the public on the management of the threatened Imperial Parrot partially arose due to the parrot receiving particular attention as a flagship species, thus conceptually turning a ‘flagship’ species to be reinterpreted as a ‘battleship’ (Douglas and Veríssimo 2013). In order to minimise potential conflicts, invasive species management campaigns should therefore carefully consider the existence of important social dynamics and political framings that can arise from constructing symbolic meanings around species.

The public are not impartial towards all species and some of the variation can be explained by appearance. For instance, green and blue birds tend to be preferred by people (Lišková et al., 2015) and a study on valuation of songbirds found people's WTP to be higher for finches than for corvids (Clucas et al., 2015). Another example is that, in general, people are have a higher WTP for the management of species that are less attractive (e.g. García-Llorente et al., 2008), and are prepared to overlook the potential negative impacts of invasive species if they are attractive (Adams et al., 2011; Lindemann-Matthies, 2016). We found that the ring-necked parakeet, which is a colourful and predominately green bird, was the most attractive of our six pest species. In line with this previous research, members of the public who rated the parakeet as the most attractive bird had a significantly higher WTA for a large population size decrease for the parakeet compared to the other species. Likewise, the same cohort had a relatively smaller WTA for small population size increases for the parakeet specifically. In contrast, people who did not prefer the ring-necked parakeet had a significant WTP for the control of the species via deterrents. These results suggest that public opposition to management, and tolerance of negative impacts, are both likely to be greater for species that people find more appealing. In turn, this might mean that the public would have to receive more information about the detrimental environmental and/or socio-economic effects of attractive invasive species, before accepting the need for management action.

In our questionnaire, lethal control was described as 'shooting/gassing/poisoning adult birds, removing/damaging bird eggs'. Throughout all the analyses, we found strong and consistent negative preferences for the use of such control measures. This highlights the importance of consulting with the public about potential population control approaches that might be adopted when developing management strategies for invasive and pest species, as ethical and welfare concerns may well equally or more important than environmental or socioeconomic ones (Perry and Perry, 2008). The preferences of the public needs to also be considered within a wider ethical debate that is ongoing between the traditional conservation biology view which considers lethal control of invasive vertebrates as a necessary trade-off in order to avoid the decline and extinction of native species and preserve diversity (Driscoll and Watson, 2019), and calls for a more 'compassionate conservation' that views the suffering of individual animals for these aims as undesirable and unjustified (Wallach et al., 2018). Nevertheless, the substantial opposition we observed may be because we focussed on birds, which are highly valued in general, more so than other taxonomic groups (Bremner and Park, 2007; Verbrugge et al., 2013; Vane and Runhar, 2016). Moreover, people might have differing preferences for separate lethal control methods. For example, it might be that they find egg removal to be more palatable than poisoning. These preferences might also be moderated by the financial costs associated with implementation.

While preferences for different species and the types of management that could be used to control their future population sizes were heterogeneous across respondents, we found no variation between people living in the UK, Germany and The Netherlands. This suggests, from a societal perspective, that developing policies across multiple countries can be appropriate.

The public are not overly concerned with the concept of nativeness. This reflects the results of other studies, which have demonstrated that people are more influenced by learning about the undesirable environmental and socio-economic outcomes caused invasive species, and that humans are responsible for introducing them and should thus be responsible for managing them (Bremner and Park, 2007; Verbrugge et al., 2013). When educating the public or conducting social marketing campaigns, people should not be treated as a homogenous group. The design of any material used to influence people's perceptions needs to be cognisant of how attractive a particular species is deemed to be by the public, as well as whether people have been exposed it to or not, as both factors have a significant bearing on whether or not they will accept management to control future population sizes.

Indeed, the key message emerging from our study is just how important it is that policies are put in place to facilitate the rapid implementation of interventions to control bird pests, because people who are yet to be exposed to the species are more likely to countenance it being managed differently to other species. If a non-native species becomes invasive, and its distribution expands, it is probable that more people will encounter it and then become resistant to supporting action to minimise future population sizes. This phenomenon will be exacerbated by the human population becoming increasingly urbanised (UN, 2015) and our towns and cities becoming more biologically homogeneous (McKinney, 2002). Taking prompt action to control invasive species also makes sense from an ecological point of view, as the probability of an intervention being successful is greater, and an economical one, because the scale of management will be smaller and the negative impacts will be less widespread (Ricciardi et al., 2017).

3.6. Acknowledgements

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3.8. Supporting information

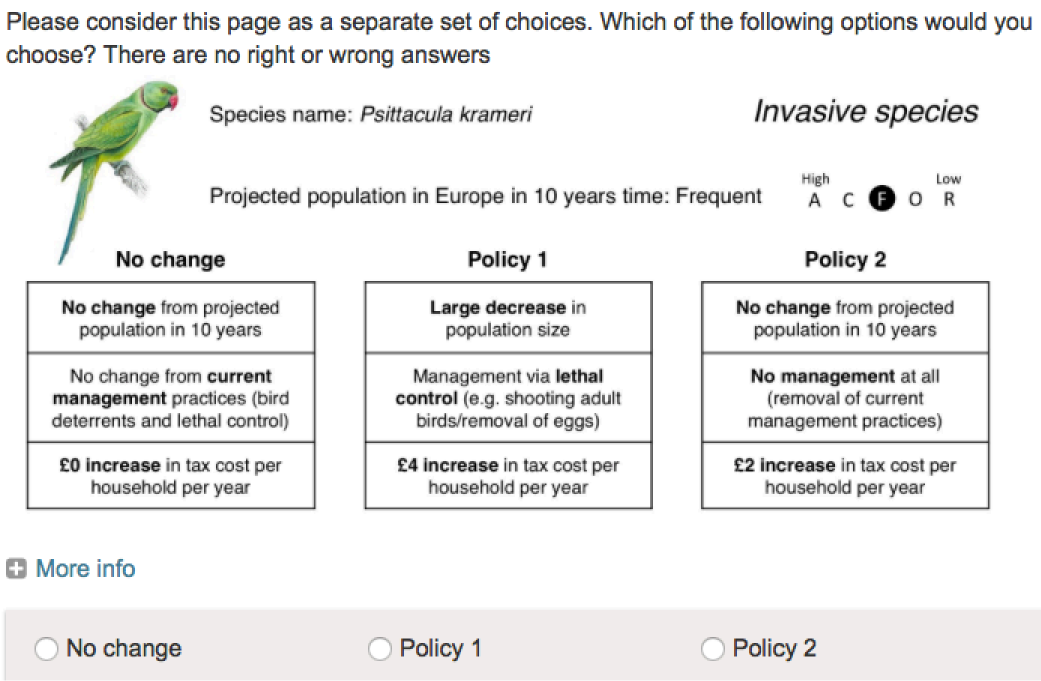
Appendix S3.8.1. The different attribute levels applied to the six bird pests used in a choice experiment, conducted across the UK, Germany and The Netherlands.

*T*o determine public preferences for the population size and management of native and invasive species. The different cost levels for the payment vehicle attribute are also provided.

Attribute	Levels	Descriptions
Population	No change in population size Large decrease in population size Small decrease in population size Small increase in population size	The change in population size from the projected population 10 years from now. Respondents were presented with the qualitative descriptor of the projected population in 10 years if current management (see row below for a definition) continues, following the ACFOR scale ('abundant', 'common', 'frequent', 'occasional' or 'rare'). Respondents were reminded that larger populations could cause greater impacts. However, they may prefer the population size to increase so they are more likely to see them in their local area.
Control	No change from current management practises (bird deterrents and lethal control) Management via just bird deterrents (e.g. nets/noise machines) Management via just lethal control (e.g. shooting adult birds/removal of eggs) No management at all (removal of all current management)	Respondents were informed that 'society currently spends money on managing pest bird species to reduce their negative impacts'. Management actions include 'bird deterrents' (e.g. nets to protect crops/buildings, lasers and noise machines to scare birds away) or 'lethal control' (e.g. shooting/gassing/poisoning adult birds, removing/damaging bird eggs). Both these options were said to reduce bird population sizes and the damage they cause. 'No management' means that all current management practices are stopped and money is spent on paying compensation for damage caused by the pest birds instead.
Cost	£0 UK, €0 DE, €0 NL £2 UK, €2 DE, €2.50 NL £4 UK, €4 DE, €4.50 NL £9 UK, €9.50 DE, €10.50 NL £12 UK, €12.50 DE, €13.50 NL	Increase in income tax cost per household per year for respondents in the United Kingdom (UK), Germany (DE) and The Netherlands (NL). The range is based on the upper and lower limits focus group and pre-testing/pilot questionnaire participants said they were willing-to-pay. The figures were converted to the nearest €/£0.50 using Purchasing Power Parity (PPP) (World Bank, 2015).

Appendix S3.8.2. Example of a choice set.

Used in a choice experiment, conducted across the UK, Germany and The Netherlands, to determine public preferences for the population size and management of native and invasive species. The example is from the 'classified' split of the questionnaire in English, which stated whether the species featured in the choice set was native or invasive. The 'not classified' version of this choice set was identical, with only the words 'Invasive Species' omitted in the top right corner. Respondents could press the 'More info' button to see an annotated example choice set to remind them of the meaning/definitions of the attributes and levels while completing the questionnaire.



Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Psittacula krameri*

Invasive species

Projected population in Europe in 10 years time: Frequent

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Large decrease** in population size	**No change** from projected population in 10 years
No change from **current management** practices (bird deterrents and lethal control)	Management via **lethal control** (e.g. shooting adult birds/removal of eggs)	**No management** at all (removal of current management practices)
£0 increase in tax cost per household per year	**£4 increase** in tax cost per household per year	**£2 increase** in tax cost per household per year

More info

No change　Policy 1　Policy 2

Appendix S3.8.3. Serial non-response protest statements

Respondents who chose the 'no change' option across all choice set were presented with the following debriefing question:

"As you always chose the 'No change' option, please indicate your primary reason for doing so from the statements listed below (choose only one):

1. It was the fastest way to get through the questionnaire
2. I am against the management of any bird species
3. I am against the management of native bird species
4. I am against the lethal control of birds
5. I do not care about the management of bird species populations
6. I would prefer bird species management to stay as it is now
7. I already pay enough tax and existing public funds should pay for bird species management
8. The trade-off between the different options made 'no change' the best choice for me in all sets
9. I do not think it is important to finance these changes in bird species management
10. I prefer to spend my money on other things
11. I could not relate to the background information provided
12. Bird species management should not be funded through taxation
13. The sets of options were difficult to relate to
14. The options were too expensive for what I would get out of bird species being managed
15. I could not afford any of the proposed option changes"

Respondents who selected 1, 7, 11, 12 or 13 were considered to be protesting against the questionnaire or the payment vehicle, and were removed from subsequent analysis (von Haefen et al., 2005; Mayerhoff et al., 2014).

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Appendix S3.8.4. Choice experiment analysis approach

To determine the relative importance of attributes within a choice experiment, complex probabilistic analysis is required. Here, we report the results of random parameter logit models, which are an extension of most basic conditional logit, and are commonly used in the choice modelling literature. It assumes the utility of a good can be described as a function of its attributes (Train, 2003). In a choice set, where alternative versions of a good are described by variation in their attributes, respondents are assumed to choose the alternative good that gives them the highest indirect utility. As it is not possible to observe perfectly an individual's utility, the Random Utility Model forms the basis of the estimation:

$$U_{ij} = V_{ij}(y_i - t_j, x_j, z_i) + \varepsilon_{ij}$$

Where U_{ij} represents individual i's indirect utility from a change in management of pest bird species. The term V_{ij} is deterministic and is a function of individual i's income y subtracted by a tax payment t for alternative j, the alternative's attributes x_j and the individual's characteristics, z_i. The error term ε_{ij} is stochastic, meaning it cannot be observed by the analyst. If we assume the error elements to be identically and independently drawn from an extreme value distribution, the Random Utility Model is specified as 'conditional logit'.

If the utility function U is linear in its arguments, and collecting all the arguments in the vector x_{ki} for a given specific alternative k among the J choice alternatives and individual i choosing, we can write $U_{ki} = \beta' x_{ki}$, where β is a vector of parameters describing alternatives in terms of: the change in population size of the bird species in the choice, the management used to control population size, and the cost of the policy option. Using the conditional logit model, the probability of an individual i choosing alternative k over a set of alternatives J is given by:

$$Pr_i(k) = \frac{\mathrm{e}^{\mu\beta' x_{ki}}}{\sum_i^J \mathrm{e}^{\mu\beta' x_{ki}}}$$

Where μ is a scale parameter that, for simplicity, is typically normalised to utility.

In our analyses, we used one of a variety of extensions to this model that allows for describing and estimating a distribution for β as random parameters, and hence accounts for preference heterogeneity in the population. This overcomes a limitation in the conditional logit model by allowing for random taste variation, unrestricted substitution patterns and correlation in unobserved factors over time (Train, 2003). This random parameter logit model (Train and Weeks, 2005) describes the probabilities as integrals of the standard conditional logit function over the distribution of βin the n'th choice occasion:

$$Pr_{in}(k) = \int \left(\frac{e^{\mu \beta_i{}' x_{ki} n}}{\sum_i^J e^{\mu \beta_i{}' x_{kin}}} \right) \varphi(\beta | b, W) d\beta$$

Here $\varphi(\beta|b, W)$ is the distribution function for β with a mean b and covariance W.

Estimation of the likelihood function based on the random parameter logit model requires assumptions and specifications to be made regarding which coefficients are random and the joint distribution of these coefficients. In our random parameter model, we assume all parameters except cost are normally distributed. Significant standard deviations were obtained in all models for all parameters (p≤0.01), except in specific cases that were noted and indicated that preferences for the characteristics were heterogeneous across the study sample. The model implies an explicit estimation of the nature of the variation in preferences across individuals, in the form of a density function, which is different from the unexplained variation in choices captured by the error term in the Random Utility Model above.

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Appendix S3.8.5. Supplementary results

Table S3.8.5.1 Socio-demographic/economic characteristics of the final sample of choice experiment respondents in the UK, Germany and The Netherlands, used to determine public preferences for the population size and management of native and invasive pest bird species. The sample is benchmarked against national population statistics for each country (Eurostat, 2016). *Please note that where sample is reported by gender, age and income, the figures may not sum to the total number of respondents for each country due to a small number of individual not wanting to disclose their socio-demographic/economic background.

Country		UK			Germany			The Netherlands		
		Sample size*	% of sample	% for country (aged 18 or over)	Sample size*	% of sample	% for country (aged 18 or over)	Sample size*	% of sample	% for country (aged 18 or over)
Number of respondents	3,008	979			1,042			987		
Gender	Male	487	49.95	49.29	554	54.00	49.3	497	50.87	49.57
	Female	488	50.05	50.71	472	46.00	50.7	480	49.13	50.43
Age	18 – 24	66	6.82	11.37	83	8.07	9.2	124	12.64	10.82
	25 – 34	205	21.18	17.22	223	21.69	15.33	194	19.78	15.40
	35 – 44	190	19.63	16.21	206	20.04	14.44	179	18.25	15.70
	45 – 54	186	19.21	17.87	253	24.61	19.58	194	19.78	18.93
	55 – 64	187	19.32	14.59	163	15.86	16.33	190	19.37	16.40
	Over 65	134	13.84	22.73	100	9.73	25.13	100	10.19	22.75
Income	Under £15k	104	12.16		151	17.36		186	23.25	
	£15k – 20k	80	9.36		157	18.05		137	17.13	
	£20k – 30k	152	17.78		131	15.06		132	16.50	
	£30k – 40k	139	16.26		119	13.68		116	14.50	
	£40k – 50k	128	14.97		98	11.26		64	8.00	
	£50k – 75k	151	17.66		92	10.57		87	10.88	
	Over £75k	101	11.81		122	14.02		78	9.75	

Table S3.8.5.2. Parameter estimates and willingness-to-pay (WTP) or willingness-to-accept (WTA), showing people's preferences for the population size and management of native and invasive bird pest species. WTP/WTA is presented in £GB per household per year. The results are from three random parameter logit models split by: (A) UK; (B) Germany, and; (C) The Netherlands. Stars indicate significance: *p≤0.05; **p≤0.01.

Model	Attribute (and levels for control and population)		Parameter estimate			Standard deviation			Willingness-to-pay/accept		
			Value		SE	Value		SE	Value		SE
A. Respondents from the UK. Based on 11,748 choices from 979 respondents (χ^2=6,136.72, pseudo-R^2=0.237, log-likelihood=-9,838.14)	No change options (ASC)		0.868	**	0.077				WTP 8.91	**	1.032
	Control	Lethal	-0.874	**	0.092	1.188	**	0.096	WTA 8.98	**	1.001
		Deterrents	-0.056		0.071	0.982	**	0.067	WTA 0.57		0.722
		No	-0.173	*	0.074	0.962	**	0.074	WTA 1.78	*	0.755
	Population	Small decrease	0.175	*	0.069	0.912	**	0.067	WTP 1.80	*	0.726
		Large decrease	-0.203	*	0.087	1.392	**	0.082	WTA 2.09	*	0.884
		Small increase	-0.500	**	0.086	1.329	**	0.078	WTA 5.13	**	0.879
	Cost		-0.097	**	0.005						
B. Respondents from Germany. Based on 12,504 choices from 1,042 respondents (χ^2=5,194.63, pseudo-R^2=0.189, log-likelihood=-11,139.73)	No change options (ASC)		0.683	**	0.072				WTP 8.63	**	1.166
	Control	Lethal	-1.000	**	0.089	1.306	**	0.091	WTA 12.62	**	1.246
		Deterrents	-0.032		0.071	1.254	**	0.064	WTA 0.40		0.892
		No	-0.095		0.071	1.185	**	0.069	WTA 1.20		0.889
	Population	Small decrease	0.093		0.064	0.859	**	0.063	WTP 1.18		0.824
		Large decrease	-0.134		0.073	1.091	**	0.069	WTA 1.70		0.917
		Small increase	-0.481	**	0.075	1.056	**	0.072	WTA 6.07	**	0.940
	Cost		-0.079	**	0.004						
C. Respondents from The Netherlands. Based on 11,844 choices from 987 respondents (χ^2=5,580.70, pseudo-R^2=0.214, log-likelihood=-10,221.61)	No change options (ASC)		0.711	**	0.076				WTP 7.74	**	1.037
	Control	Lethal	-0.943	**	0.093	1.249	**	0.094	WTA 10.27	**	1.088
		Deterrents	-0.076		0.071	1.105	**	0.066	WTA 0.83		0.769
		No	-0.140		0.075	1.186	**	0.074	WTA 1.52		0.815
	Population	Small decrease	0.168	*	0.068	0.950	**	0.067	WTP 1.82	*	0.757
		Large decrease	-0.280	**	0.080	1.128	**	0.074	WTA 3.04	**	0.861
		Small increase	-0.563	**	0.081	1.216	**	0.079	WTA 6.13	**	0.886
	Cost		-0.092	**	0.004						

Table S3.8.5.3. Parameter estimates and willingness-to-pay (WTP) or willingness-to-accept (WTA), showing people's preferences for the population size and management of native and invasive bird pest species. WTP/WTA is presented in £GB per household per year. The results are from four random parameter logit models split by: (A) native birds, not stated; (B) native birds, stated; (C) invasive birds, not states, and; (D) invasive birds, stated. Stars indicate significance: *p≤0.05; **p≤0.01. †Please note that the standard deviation of the random parameter was not significant and thus not included in these models.

Model	Attribute (and levels for control and population)		Parameter estimate			Standard deviation			Willingness-to-pay/accept		
			Value		SE	Value		SE	Value		SE
A. Native birds, not stated. Based on 8,898 choices from 1,483 respondents (χ^2=3,333.68, pseudo-R^2=0.170, log-likelihood=-8,108.61)	No change options (ASC)		0.541	**	0.089				WTP 4.82	**	0.968
	Control	Lethal	-1.236	**	0.292	1.507	**	0.297	WTA 11.02	**	2.735
		Deterrents	-0.119		0.079	1.573	**	0.074	WTA 1.06		0.702
		No management	-0.132		0.077	1.250	**	0.092	WTA 1.18	*	0.682
	Population	Small decrease	0.153	*	0.076	1.140	**	0.074	WTP 1.37	*	0.710
		Large decrease†	1.209	**	0.097				WTP 10.78	**	0.783
		Small increase	-0.683	**	0.091	1.098	**	0.111	WTA 6.09	**	0.848
	Cost		-0.112	**	0.007						
B. Native birds, stated. Based on 9,159 choices from 1,525 respondents (χ^2=3,458.77, pseudo-R^2=0.171, log-likelihood=-8,322.92)	No change options (ASC)		0.627	**	0.090				WTP 5.41	**	0.969
	Control	Lethal	-1.351	**	0.312	1.963	**	0.294	WTA 11.66	**	2.827
		Deterrents	-0.012		0.079	1.556	**	0.074	WTA 0.10		0.679
		No management	-0.175	*	0.080	1.415	**	0.096	WTA 1.51	*	0.684
	Population	Small decrease	0.185	*	0.077	1.226	**	0.074	WTP 1.60	*	0.703
		Large decrease†	1.421	**	0.098				WTP 12.27	**	0.795
		Small increase	-0.752	**	0.096	1.311	**	0.108	WTA 6.49	**	0.864
	Cost		-0.116	**	0.007						
C. Invasive birds, not stated. Based on 8,898 choices from 1,483 respondents (χ^2=5,772.47, pseudo-R^2=0.295, log-likelihood=-6,889.22)	No change options (ASC)		1.683	**	0.129				WTP 30.92	**	8.229
	Control	Lethal	-0.504	**	0.094	1.145	**	0.101	WTA 9.26	**	2.323
		Deterrents	-0.334	*	0.130	1.659	**	0.166	WTA 6.13	*	2.674
		No management	-0.185		0.114	1.836	**	0.129	WTA 3.40		2.122
	Population	Small decrease	-0.845	**	0.206	1.898	**	0.177	WTA 15.53	**	5.969
		Large decrease	-0.250	*	0.118	1.654	**	0.088	WTA 4.60		2.367
		Small increase	0.116		0.125	1.489	**	0.107	WTP 2.13		2.390
	Cost		-0.054	**	0.012						

D. Invasive birds, stated. Based on 9,150 choices from 1,525 respondents (χ^2=5,180.36, pseudo-R^2=0.257, log-likelihood=-7,462.12)	No change options (ASC)		1.283	**	0.122				WTP 19.94	**	4.728
	Control	Lethal	-0.537	**	0.085	1.083	**	0.096	WTA 8.35	**	1.692
		Deterrents	-0.348	**	0.124	1.624	**	0.173	WTA 5.41	**	2.063
		No management	-0.330	**	0.106	1.619	**	0.117	WTA 5.12	**	1.750
	Population	Small decrease	-0.897	**	0.194	2.072	**	0.168	WTA 13.95	**	4.506
		Large decrease	-0.289	**	0.111	1.658	**	0.081	WTA 4.49	*	1.867
		Small increase	-0.073		0.119	1.475	**	0.102	WTA 1.14		1.840
	Cost		-0.064	**	0.011						

Table S3.8.5.4. Parameter estimates and willingness-to-pay (WTP) or willingness-to-accept (WTA), showing people's preferences for the population size and management of native and invasive bird pest species. WTP/WTA is presented in £GB per household per year. The results are from two random parameter logit models split by: (A) people who have seen ring-necked parakeets in the city they live in, and; (B) people who have not seen ring-necked parakeets local to where they live. Stars indicate significance: *p≤0.05; **p≤0.01. Please note, the interaction term associated with ring-necked parakeets and a small decrease in population size could not be estimated within the choice experiment design.

Model	Attribute (and levels for control and population)		Parameter estimate			Standard deviation			Willingness-to-pay/accept		
			Value		SE	Value		SE	Value		SE
A. Respondents who have seen a parakeet in their city. Based on 10,380 choices from 865 respondents (χ^2=4360.70, pseudo-R^2=0.190, log-likelihood=-9,223.25)	No change options (ASC)		0.642	**	0.083				WTP 7.50	**	1.213
	Control	Lethal	-0.859	**	0.099	1.195	**	0.101	WTA 10.03	**	1.229
		Deterrents	-0.144		0.078	1.161	**	0.071	WTA 1.68		0.897
		No management	-0.121		0.080	1.096	**	0.080	WTA 1.41		0.928
	Population	Small decrease	0.117		0.076	1.011	**	0.070	WTP 1.37		0.896
		Large decrease	-0.112		0.091	1.245	**	0.079	WTA 1.31		1.059
		Small increase	-0.488	**	0.087	1.166	**	0.084	WTA 5.70	**	1.005
	Cost		-0.086	**	0.005						
	Interactions with the ring-necked parakeet choice set										
	Lethal X Parakeet		0.155		0.123				WTP 1.81		1.436
	Deterrents X Parakeet		0.589	**	0.211				WTP 6.88	**	2.465
	No management X Parakeet		-0.337	**	0.122				WTA 3.94	**	1.411
	Large decrease X Parakeet		0.098		0.101				WTP 1.15		1.179
	Small increase X Parakeet		-0.280		0.159				WTA 3.27		1.848
B. Respondents who have not seen a parakeet in their city. Based on 25,716 choices from 2143 respondents (χ^2=12,673.01, pseudo-R^2=0.224, log-likelihood=-21,915.41)	No change options (ASC)		0.672	**	0.053				WTP 6.88	**	0.667
	Control	Lethal	-1.078	**	0.070	1.320	**	0.066	WTA 11.04	**	0.765
		Deterrents	-0.085		0.049	1.162	**	0.046	WTA 0.87		0.503
		No management	-0.114	*	0.053	1.213	**	0.051	WTA 1.16	*	0.541
	Population	Small decrease	0.097	*	0.047	0.855	**	0.044	WTP 0.99	*	0.486
		Large decrease	-0.153	**	0.059	1.154	**	0.053	WTA 1.56	**	0.601
		Small increase	-0.519	**	0.056	1.155	**	0.052	WTA 5.31	**	0.565
	Cost		-0.098	**	0.003						
	Interactions with the ring-necked parakeet choice set										
	Lethal X Parakeet		0.070		0.085				WTP 0.72		0.869
	Deterrents X Parakeet		0.115		0.137				WTP 1.17		1.397
	No management X Parakeet		-0.578	**	0.082				WTA 5.91	**	0.839
	Large decrease X Parakeet		-0.456	**	0.070				WTA 4.67	**	0.722
	Small increase X Parakeet		-0.405	**	0.101				WTA 4.14	**	1.030

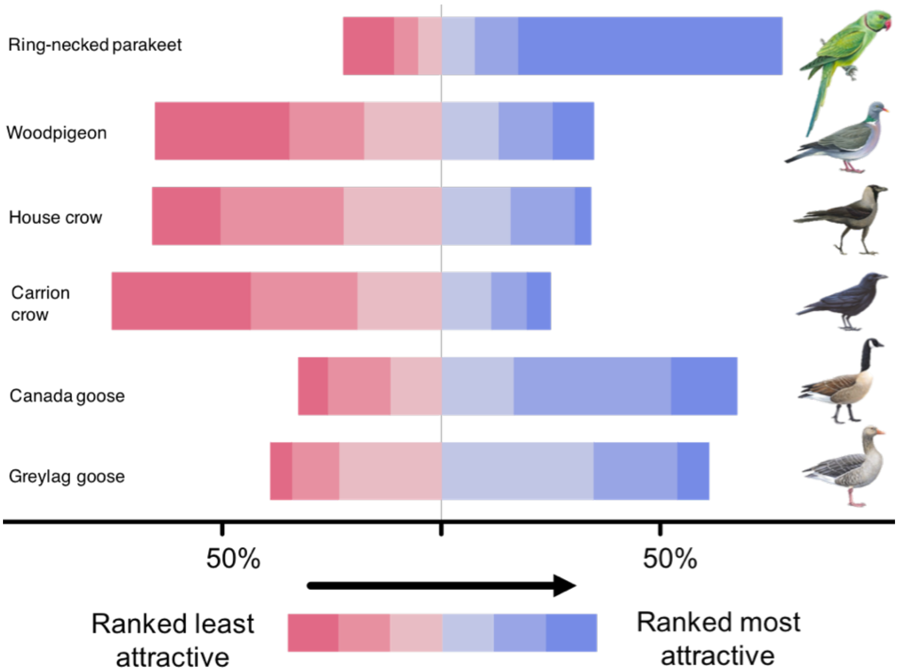

Figure S3.8.5.5. The attractiveness ranking of the six bird pest species used in a choice experiment, conducted across the UK, Germany and The Netherlands, to determine public preferences for the population size and management of native and invasive species. The results are presented as the percentage of respondents (N=3,008) ranking the birds from 1-6 with the darkest blue representing the highest ranking (6).

Table S3.8.5.6. Parameter estimates and willingness-to-pay (WTP) or willingness-to-accept (WTA), showing people's preferences for the population size and management of native and invasive bird pest species. WTP/WTA is presented in £GB per household per year. The results are from two random parameter logit models split by: (A) people who ranked the ring-necked parakeet as the most attractive bird, and; (B) people who did not rank the ring-necked parakeet as the most attractive bird (ranked 1-5). Stars indicate significance: *p≤0.05; **p≤0.01. Please note, the interaction term associated with ring-necked parakeets and a small decrease in population size could not be estimated within the choice experiment design.

Model	**Attribute (and levels for control and population)**		**Parameter estimate**			**Standard deviation**			**Willingness-to-pay/accept**		
			Value		**SE**	**Value**		**SE**	**Value**		**SE**
A. Respondents who ranked the parakeet as the most attractive bird. Based on 21,816 choices from 1,818 respondents (χ^2=11,755.29, pseudo-R^2=0.245, log-likelihood=-18,089.68)	No change options (ASC)		0.691	**	0.059				WTP 6.38	**	0.654
	Control	Lethal	-1.052	**	0.074	1.133	**	0.075	WTA 9.71	**	0.715
		Deterrents	-0.120	*	0.054	1.138	**	0.050	WTA 1.11	*	0.496
		No management	-0.120	*	0.056	1.044	**	0.055	WTA 1.11	*	0.517
	Population	Small decrease	0.149	**	0.052	0.899	**	0.049	WTP 1.38	**	0.488
		Large decrease	-0.131	*	0.066	1.243	**	0.056	WTA 1.21	*	0.609
		Small increase	-0.609	**	0.063	1.189	**	0.058	WTA 5.62	**	0.578
	Cost		-0.108	**	0.003						
	Interactions with the parakeet choice set										
	Lethal X Parakeet		-0.037		0.096				WTA 0.35		0.885
	Deterrents X Parakeet		0.151		0.148				WTP 1.39		1.367
	No management X Parakeet		-0.591	**	0.089				WTA 5.46	**	0.818
	Large decrease X Parakeet		-0.512	**	0.077				WTA 4.73	**	0.723
	Small increase X Parakeet		-0.266	*	0.111				WTA 2.45	*	1.021

B. Respondents who did not rank the parakeet as the most attractive bird. Based on 14,280 choices from 1,190 respondents (χ^2=5,458.67, pseudo-R^2=0.173, log-likelihood=-12,958.85)	No change options (ASC)		0.625	**	0.070				WTP 8.42	**	1.209
	Control	Lethal	-0.885	**	0.087	1.354	**	0.086	WTA 11.92	**	1.270
		Deterrents	-0.066		0.066	1.196	**	0.062	WTA 0.88		0.886
		No management	-0.092		0.070	1.255	**	0.063	WTA 1.24		0.936
	Population	Small decrease	0.026		0.063	0.930	**	0.057	WTP 0.35		0.849
		Large decrease	-0.200	**	0.076	1.141	**	0.066	WTA 2.70	**	1.019
		Small increase	-0.392	**	0.072	1.176	**	0.066	WTA 5.28	**	0.965
	Cost		-0.074	**	0.004						
	Interactions with the parakeet choice set										
	Lethal X Parakeet		0.231	*	0.103				WTP 3.11	*	1.393
	Deterrents X Parakeet		0.407	*	0.181				WTP 5.49	*	2.440
	No management X Parakeet		-0.350	**	0.107				WTA 4.71	**	1.428
	Large decrease X Parakeet		0.019		0.085				WTP 0.25		1.152
	Small increase X Parakeet		-0.477	**	0.134				WTA 6.43	**	1.798

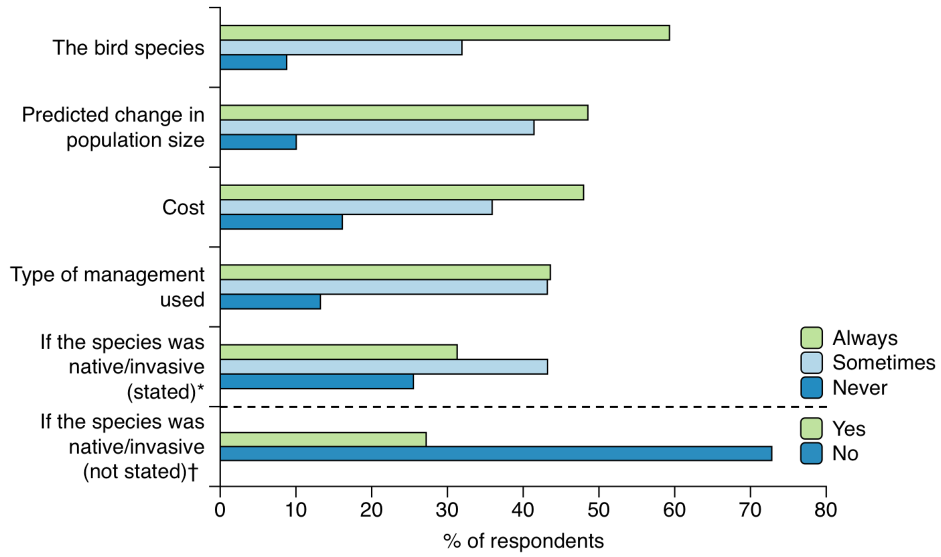

Figure S3.8.5.7. Responses to a question asking how often respondents considered various factors when making choices in the questionnaire (N=3,008). *This item was only asked of respondents who did the questionnaire split which classified species as native/invasive (n=1,525). †This item was only asked of respondents who did the questionnaire split which did not classify species as native/invasive (n=1,483).

Chapter 4. Creating a buzz in the city: how the creation of pollinator-friendly wildflower meadows influences urban greenspace users' perceptions of ecological characteristics and connectedness to nature

Due for submission to *Scientific Reports*.
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4.1. Abstract

Increasingly research is demonstrating that urban greenspaces can provide important habitats and resources for biodiversity, as well as improving the health and well-being of people in cities. However, the role that biodiversity plays in delivering such ecosystem services within greenspaces, and the extent to which individuals perceive characteristics of biodiverse environments is poorly understood. This study used experimental wildflower meadow plots planted in urban greenspaces across three UK cities, as a case study of a biodiversity conservation intervention with the potential to provide co-beneficial ecosystem services. Wildflower meadows can support and augment pollinating insect populations and could also provide benefits to park users in terms of increasing the opportunity and quality of interactions with nearby nature. Areas of greenspaces were assigned to one of three treatment groups: control sites constituting amenity grass, native perennial meadows and non-native annual meadows. Biodiversity surveys established the diversity and abundance of flowering plants and pollinators, and responses to questionnaires were collected *in situ* across 17 sites to N = 589 respondents. Regression analyses were used to assess associations between perceptions and objective measures of biodiversity. General Linear Mixed Models (GLMM) were used to establish if any of these, or individual characteristics, influenced people's connectedness to nature. We found that urban greenspace visitors could broadly perceive species richness of plants, but could not perceive nativeness, and that people's estimates of quality of sites for pollinators predicted pollinator abundance and diversity. None of these factors influenced people's connectedness to nature, with the only site-level perceived factor to do so being site colourfulness. These findings have implications for understanding how people perceive biodiversity and how different experiences in nature relate to people's self-reported connectedness to nature.

4.2. Introduction

World-wide, more than half of all people now live in urban rather than rural areas, and this proportion is expected to continue to rise (UNDP, 2011). In developed regions, this is already much higher, such as in the UK where around 90% of people live in urban areas. Alongside the pressures that urbanisation places on biodiversity (Grimm et al., 2008; Aronson et al., 2017), rapid urban development also presents challenges for cities' human inhabitants, through a reduction in ecosystem services and a lack of opportunity for people to interact with nature (Turner et al., 2004; Soga and Gaston, 2016). This has led some authors to argue that people are becoming increasingly 'disconnected' from nature, due to a lack of experiences with biodiverse environments (Wilson, 1984; Miller, 2005). These trends are especially of concern given a substantial body of evidence that demonstrates the mental and physical well-being benefits of exposure to nature, compared to urban built environments (McMahan and Estes, 2015; Hartig and Kahn, 2016). As urban land cover is forecast to triple between 2000 and 2030, many of the city landscapes that will exist in 2030 have yet to be built (Seto et al., 2012). There is, therefore, broad interest in the design of urban areas which integrate nature and natural features that can serve multiple purposes, such as reducing the societal burden of ill health, addressing food security and benefitting biodiversity (Aronson et al., 2017).

Across a range of disciplines, studies have demonstrated that experiencing nature can improve cognitive functioning (Berto, 2005; Berman et al., 2008), elevate subjective well-being (Johansson et al., 2011; Luck et al., 2011; White et al., 2017), reduce stress levels (Ulrich et al., 1991; Hansmann et al., 2007), and strengthen people's bonds with others and the natural environment (Mayer et al., 2009; Weinstein et al., 2015; Richardson et al., 2016). Connectedness to nature, defined as an individual's emotional and cognitive bond to the natural world (Mayer and Frantz, 2004), is a psychological construct, understood by some to be one of the benefits of experiencing natural environments (e.g. Wyles et al., 2017). Connectedness to nature has been shown to produce benefits both for the individual and potentially for the environment. For example, a greater connectedness to nature has been associated with increased overall life satisfaction (Mayer and Frantz, 2004; Hinds and Sparks, 2008), happiness (Tam, 2013; Zelenski and Nisbet, 2014) and increased positive and decreased negative emotions (Howell et al., 2011; Nisbet and Zelenski, 2011). Additionally, a small evidence base suggests that people with a greater connectedness to nature have reported to perform more pro-environmental behaviours (Hinds and Sparks, 2008; Barbaro and Pickett, 2016; Pensini et al., 2016; Richardson et al., 2016). Connectedness to nature has been conceptualised as both a stable personality trait (e.g. Mayer and Frantz, 2004; Nisbet et al., 2011) and as a state indicator that differs experientially with a person's surrounding context (Mayer et al., 2009; Weinstein et al., 2009; Nisbet and Zelenski, 2011). Although measured using multiple psychological tools, which measure slightly different aspects, a recent meta-analysis found all measures of connectedness to nature were correlated with each other and related to subjective well-being (Capaldi et al., 2014).

The literature on connectedness to nature, and human-nature relationships more broadly, has tended to use a broad definition of nature, treating spaces as homogenous and not considering variations in type and quality. Often, there has been a tendency to focus on differences between built-up versus greenspace areas in urban settings, rather than distinguishing between quality within or between greenspaces. This simplistic view risks masking how specific greenspace characteristics could lead to potentially different experiences of nature, which in turn may be associated with a variety of outcomes (Dallimer et al., 2012). Areas vary in their biodiversity value and in their quality in delivering ecosystem services, and understanding potential trade-offs and synergies between different outcomes could help prioritise environment management. The studies that have considered how and if specific components of biodiversity are perceived and lead to benefits in terms of health and well-being have mixed results (Lovell et al., 2014). Across a range of environments, people express an aesthetic appreciation for, and want of, a greater number of species (Lindemann-Matthies et al., 2010a; 2010b; Fernandez-Cañero et al., 2013; Lindemann-Matthies and Marty, 2013; Shwartz, et al., 2014). Yet, studies that have examined the relationship between actual species richness and people's self-reported well-being *in-situ* are inconclusive. For example, Dallimer et al. (2012) found an inconsistent relationship between actual plant, butterfly and bird richness and well-being. They however also found that well-being was related to the richness of species that respondents perceived to be present. Another study found that people had a poor ability to estimate the number of plant species in public urban gardens and did not notice an increase in plant richness after an experimental manipulation (Shwartz et al., 2014). Using a series of experiments Lindemann-Matthies et al. (2010a) found that people could broadly perceive differences between high and low plant species richness, but consistently overestimated richness when it was low and underestimated it when it was high. Interestingly, communities of plants with the same number of species were perceived to be more species rich and more attractive when their evenness (a measure of how equal the number of individuals of each species in a community) was high. These studies emphasise the importance of understanding people's perceptions of species richness and other ecological characteristics and how this relates to ecological reality.

In this study, we used a quasi-experimental approach, manipulating the ecological quality of areas within urban greenspaces, in order to investigate two interrelated sets of questions: (i) Can people accurately estimate and perceive ecological characteristics such as, floral richness, nativeness and the quality of sites for pollinators? (ii) Which ecological and individual factors predict people's state of connectedness to nature in greenspaces?

4.3. Methodology

4.3.1. Study system

Mown amenity grass, managed primarily for recreation, is one of the most common forms of urban greenspace, especially in temperate regions (Forestry Commission, 2006; Irvine et al., 2009). These areas support a relatively low invertebrate diversity and abundance due to their low plant diversity, are typically dominated by a few grass species (Dover, 2015) and require regular mowing which limits structural diversity (Garbuzov et al., 2015). Due to the decreasing financial resources available for urban greenspace management (Heritage Lottery Fund, 2016), there has been increased interest in vegetation types which require less intensive management, and are therefore less costly, than amenity grass (Klaus, 2013), such as urban wildflower meadows (hereafter urban meadows). Recent research demonstrates the potential of urban areas to support a high diversity and abundance of native pollinators (Osborne et al., 2008; Baldock et al., 2015). Increasing the number of flowers in an area is one measure that could increase the value of cities for pollinator conservation (Hall et al., 2017) and planting urban meadows, containing beneficial flowers for insect pollinators, has become increasingly popular in urban areas in the UK in recent years (e.g. River of Flowers, 2013; Buglife, 2017). The interest in the establishment of urban meadows is not just due to cost savings or the refuge they provide for pollinators, but also due to their potential to provide cultural services for people, such as aesthetic enjoyment and the associated benefits of interacting with nature. However, the extent to which people perceive various characteristics of urban meadows, and their potential to provide these benefits is relatively unknown. The study used a wider existing multi-city ecological experiment taking place in the UK (Urban Pollinators Project UPP, 2017). As part of the UPP, meadows containing nectar- and pollen-rich plant species were established in 2012 and 2013, in areas of amenity grass in UK cities, to assess the effects of sown flower meadows for insect pollinators in urban areas. This provided an opportunity to study the responses of people to this intervention, as a natural experiment.

4.3.2. Site selection

We selected three cities involved in the UPP, Bristol, Leeds and Edinburgh (Figure 4.1.). These spanned the latitudinal gradient of the UK and were broadly comparable, all being among the top 11 most populous city regions in the UK (ONS, 2016) and included parks in more/less affluent parts of each city. Meadows sown in the UPP were 300 m^2 in size and mostly rectangular in shape (Figure 4.2.). Two types of urban meadow were established as part of the UPP, comprising of different commercially available seed mixes and requiring different management intensities. Perennial meadows contained 100% native plant species, and contained common UK wildflowers, visually dominated by white flowers such as common yarrow (*Achillea millefolium*) and Oxeye daisy (*Leucanthemum vulgare*) and pink flowers such as musk mallow (*Malva moschata*). Annual meadows contained a mix of native and non-native species, flower for one season and require resowing every year. These typically contained a larger variation in colours, including orange Californian poppies (*Eschscholtzia californica*) and blue cornflowers (*Centaurea cyanus*) (for a full list species in the seed mixes see Supporting Information S4.7.1.).

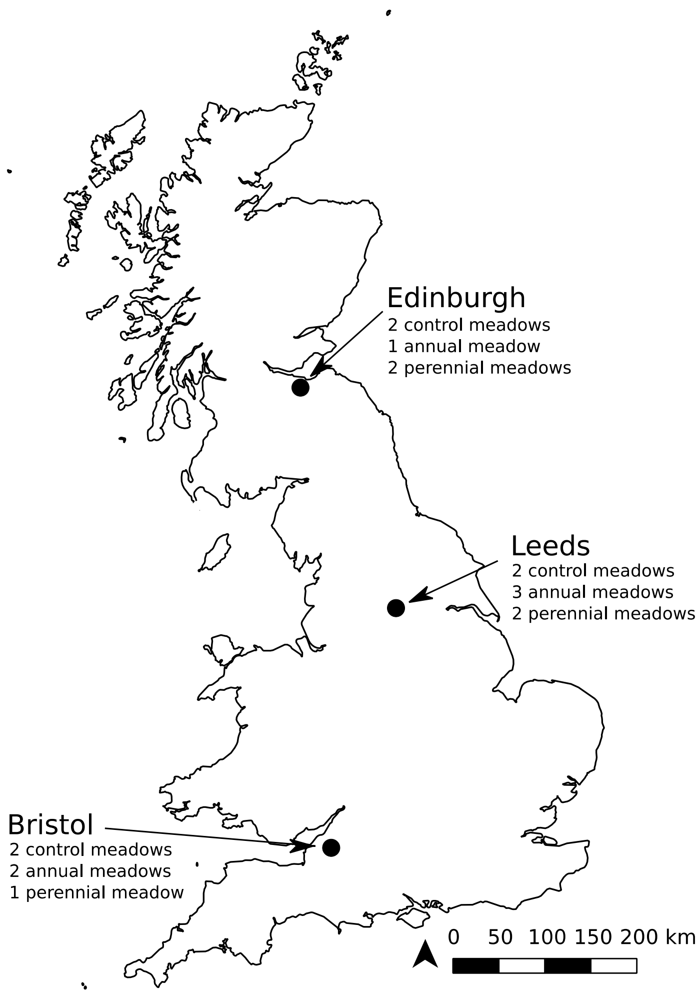

Figure 4.1. The location of the three British cities and number of study sites sampled in each city (for a full list of sites see Table S4.7.1.).

Figure 4.2. The experimental design of the study included (i) perennial meadows, (ii) annual meadows, (iii) control sites.

To represent a range of meadow types, we selected 17 sites within 11 public parks in the three cities, on the basis of sites being publicly accessible and therefore likely to receive sufficient numbers of visitors. All selected sites were surrounded by residential areas and were visited by local people. Six greenspaces included both a meadow and a paired 'control' site (i.e. an area of amenity grass that had not been turned into an urban meadow). This was to allow for comparison between people's perceptions of meadows types. Control meadows were marked out to show the area where an urban meadow would hypothetically be and were placed at a suitable distance so that the meadow was not visible. In some smaller parks this was not possible, as park users would be able to see the meadows in control locations, so no control was included. We therefore had three quasi-experimental site treatments (i) perennial meadows (ii) annual meadows and (iii) control meadows constituting of equally sized amenity grass areas.

4.3.3. Biodiversity surveys

Floral and pollinator sampling were both undertaken using transects. Transects were 56 m in length around the outer edge of each meadow and sampled 1 m into the meadow. Surveys of transects were started from a randomly chosen corner and continued in a clockwise direction. Subsequent transects followed the same start point and direction to ensure consistency. Control sites were sampled in the same way, by marking out areas of 300 m^2 with brightly coloured pegs. Floral abundance was surveyed every 8 m along the transect in 1 m x 1 m quadrats, beginning at 8 m. The number, identity, and floral units (the number of individual flowering heads) of all flowering plants found in the quadrat were recorded (excluding docks, nettles, grasses, sedges, rushes and wind pollinated trees). This was done because although a known seed mix was sown, the composition of flowers changed over time, and a number of self-seeding species grew in each site. After the transect survey was completed, any additional flowering species seen in the meadow were also recorded, in order to establish the overall meadow species richness. Insect pollinators were sampled via a transect walk that began from the same starting corner of the meadow as the floral survey, and any pollinators observed and the flower they were observed upon were recorded. These pollinators were identified to morphospecies groups in the field (see Supporting Information S4.7.2. for groups adapted from Garbuzov and Ratneiks, 2014). The status of plants (i.e. native, archaeophyte, neophyte) were categorised according to the Online Atlas of the British and Irish Flora (2017).

4.3.4. Questionnaire design

To understand whether visitors could perceive the ecological characteristics of the flower meadows, we asked respondents to estimate the number of different species of flowering plant they thought were in the site. A five-point scale was constructed on the basis of the actual variation in species richness present across sites ranging from 'less than 5', '6 to 10', '11 to 20', '21 to 30' and 'more than 30' species. To assess perceptions of the proportion of native species in each meadow a five-point scale was used ranging from 'no native plants', 'about a quarter native', 'about half native', 'about three-quarters native' to 'all native plants'. To gauge perceptions of colour, we asked people to rate the colourfulness of each site on a measure of 'very few colour' = 1 to 'very many colours' = 5. To understand respondents' perceptions of the relative quality of areas for pollinators, we asked people to indicate on a five-point scale 'do you think this area provides useful resources (e.g. breeding sites, food and shelter) for pollinating insects (e.g. bees and hoverflies)' from 'poor (not useful)' = 1 to 'excellent (very useful)' = 5. To measure the frequency to which respondents tend to spend time in open spaces, we used an adapted version of the Monitor of Engagement with the Natural Environment (MENE) question (Natural England, 2014), which asks on how many occasions in the previous seven days respondents have been out of doors. We also asked respondents if they were members of any wildlife conservation or natural heritage organisations, recorded if they were walking a dog, their household income, age, education, employment and ethnicity (according to the groupings used in the 2011 census; UK Data Service, 2017).

To understand if people's connection to nature varied due to any biophysical factors, or their perception of the local environment, an adapted version of the Connectedness to Nature Scale (CNS) state version was used (Mayer et al., 2009). This is a version of the original trait version of the CNS, which includes statements to indicate how individuals assessed themselves 'in the moment', and has previously been shown to effectively determine experiential changes depending on environmental factors. Participants responded on a 7-point scale where 'strongly disagree' = 1 and 'strongly agree' = 7. The reliability and internal consistency of the CNS scale on our data was high (Cronbach's α = 0.87, N = 577 individuals with complete CNS responses). Based on eigenvalues and by inspecting the scree plot, we confirmed that the scale consisted of one factor. The eigenvalue of this single factor was 5.72, explaining 44% of the variance in the scale items. Therefore, in analyses we used respondents mean CNS score ranging from 1 = 'low connectedness to nature' to 7 = 'high connectedness to nature'. The questionnaire was piloted with 16 people in park areas with urban meadows, to examine public comprehension of the items and scales used. The wording and explanation of questions were subsequently refined.

4.3.5. Questionnaire data collection

Questionnaires were delivered *in situ* next to the urban meadows or control sites by six trained interviewers, during the peak flowering season of July and August 2014. To represent the range of people using greenspaces, each site was visited at least once during four timeslots; weekdays and weekends, and during daytime and early evenings. A consistent method of guiding respondents through the questionnaire was used and prior to starting the questionnaire, each participant was given assurance of anonymity. Respondents were asked to provide verbal informed consent and made aware that their participation was voluntary and that no compensation would be provided. All respondents were over 18 and we received ethical approval from the University of Kent before proceeding with the study. Our sample was non-random and self-selected (i.e. we did not interview people who did not visit the greenspaces). Nevertheless, our objective was to represent and understand the perceptions of current greenspace visitors and not to characterise the difference between visitors and non-visitors.

4.3.6. Statistical analysis

All analyses were undertaken using R (R Core Team, 2017). G-tests of goodness of fit were used at α level 0.05, to assess where the socio-demographics of the sampled respondents differed in their distribution from the city population in 2014, according to Eurostat (2017). To create metrics of people's perceptions at a site level, mean perceived richness scores were calculated, ranging from 1 = all respondents choosing the lowest category to 5 = all respondents choosing the highest category. In the same way, a perceived nativeness scale was constructed based on the perceived nativeness at each site, ranging from 0 = all respondents thought there were no native species to 1 = all respondents thought all plant species were native. These measures only allow us to investigate perceptions of ecological characteristics (floral richness and nativeness) at a site level. Therefore, to measure individuals' accuracy, we created an index of accuracy where 0 = respondent choose the correct category, -4 = respondent's perception was four categories lower than the measured, 4 = respondents perception was four categories higher than correct. Kruskal-Wallis tests were used to compare the distribution of these accuracy scores between meadow treatment types, and Dunn post-hoc tests used to determine which groups (control, perennial and annual) differed from one another (Zar, 2010).

Shannon's evenness and diversity index was calculated using natural logs for flowering plant species and for pollinator morphospecies groups (Magurran, 2004). Linear regression was used to assess the relationships between ecological variables, and between ecological and measures of individuals perceptions at a site level. For each linear regression, the assumptions of normality of residuals and homoscedasticity were tested via Q-Q and scale-location diagnostic plots. Floral and pollinator abundance were $\log_{10} + 1$ transformed prior to analyses, and this significantly improved the assumption of normality of residuals.

To investigate the relationship between connectedness to nature and ecological characteristics, individuals' perceptions and socio-demographic factors, General Linear Mixed Models (GLMM) were used. To do this, we excluded sites which did not include a control meadow so that we could just examine changes between sites of different ecological characteristics. This left three annual sites and three perennial sites each paired with a control site within the same park (for a list of sites see Table S4.7.1.). Our response variable, mean connectedness to nature, was left skewed, so was transformed by squaring the variable (mean CNS)^2. We confirmed that this improved normality of residuals, and that it was therefore appropriate to use a Gaussian error structure, via Q-Q diagnostic plots and Shapiro-Wilk normality test. Residual diagnostics of final models were plotted using the DHARMa package, as misspecifications in GLMMs cannot be interpreted with standard residual plots (DHARMa, 2017). Two crossed random effects were included in the models, to account for unobserved heterogeneity in our data due to the experimental design. These were the park identity, to control for any contextual variation between different parks, and interviewer identity, to control for any variation in responses due to different people collecting responses. As ecological characteristics were correlated (as was apparent from earlier analyses), floral species richness and floral nativeness were chosen as predictors of connectedness to nature, as these were most correlated and could best represent other variables. The created measures of individuals' perceptions of the meadows characteristics (i.e. perceived floral richness, perceived proportion of nativeness, perceived pollinator quality and rating of colourfulness) were included as numeric terms in models. We also included the accuracy metrics (transformed onto a positive scale so that 0 = least accurate to 4 = most accurate)

Individuals' characteristics considered the most likely to influence connectedness to nature (gender, age group) were also modelled. The number of trips taken outdoors in the last 7 days ($\log_{10} + 1$) was transformed prior to inclusion within models due to a skewed distribution. Also included was whether the individual was walking a dog, ethnicity (groups reduced to white British or other ethnic groups due to small numbers within other ethnicity categories), and membership of conservation or natural heritage organisation. We initially created unadjusted models containing just the ecological predictors (floral species richness and nativeness). However, we did not find a difference in outcome between these models and those that included the additional confounding factors (Table S4.7.3.) and therefore only the results of the full model are included here. Collinearity between explanatory variables was tested and deemed acceptable, as no variable had a variance inflation factor greater than three (Zuur et al., 2009). We took an information-theoretic approach to model selection, comparing all candidate models and identifying the most parsimonious solution (Burnham and Anderson, 2003; Whittingham et al., 2006). Only candidate models with a

ΔAIC_C < 4 (change in second order Akaike Information Criterion) were included in the model set used for model averaging and as such, implausible models with low AIC weights were eliminated from the analysis solution (Burnham and Anderson, 2003; Bolker et al., 2009). Maximum likelihood (ML), rather than restricted maximum likelihood (REML) was used in model estimation, in order to allow for comparisons between models with AICs (Zuur et al., 2009). Averaged parameter estimates (β), unconditional standard errors (SE), lower and upper 95% confidence intervals (LCI and UCI) and relative variable importance factors (RI) are reported for the final GLMM.

4.4. Results

A total of 1,489 people were approached and this resulted in an overall response rate of 40% (N = 589). A median of 33 questionnaires were completed per site (range: 24-45; IQR: 9). Although our sample was comprised of self-selected greenspace visitors, the sample was representative of each city with regards to gender (Leeds: $G_{(2,1)} = 2.73$, $p = 0.098$; Bristol: $G_{(2,1)} = 0.49$, $p = 0.486$; Edinburgh: $G_{(2,1)} = 1.80$, $p = 0.592$). Age was representative in Leeds ($G_{(2,5)} = 2.24$, $p = 0.814$) and Edinburgh ($G_{(2,5)} = 6.31$, $p = 0.277$) but our sample was significantly under-representative of some age groups (35 – 64 year olds) in Bristol ($G_{(2,5)} = 11.44$, $p < 0.05$). Respondents predominately recorded their ethnicity as White (92% in Leeds, 96% in Bristol and 90% in Edinburgh) and subsequently, our sample was significantly under-representative of non-white ethnicities in Leeds ($G_{(2,1)} = 9.42$, $p < 0.01$) and Bristol $G_{(2,1)} = 24.33$, $p < 0.001$, but representative in Edinburgh ($G_{(2,1)} = 0.30$, $p = 0.584$) (Table S4.7.2.). Respondents covered a broad household income range, comprising of individuals below and above the lower and upper national deciles of income (< £5,199 to > £52,000 per annum before tax).

4.4.1. Biodiversity characteristics of sites

The species richness of flowering plants ranged between one to 31 across the meadows, whereas pollinator morphospecies richness ranged from zero to seven groups (Table 4.1.). We found significant linear relationships between all metrics of pollinator and floral biodiversity when considering all 17 sites (Table 4.2.). The strongest predictor of all pollinator diversity metrics was floral species richness (log_{10} pollinator abundance, $F_{1,15}$ = 87.55, $p < 0.001$, $R^2 = 0.85$; pollinator morphospecies richness, $F_{1,15} = 67.50$, $p < 0.001$, $R^2 = 0.82$; pollinator Shannon's diversity $F_{1,15} = 43.92$, $p < 0.001$, $R^2 = 0.75$). This reveals that, as expected, with the creation of flower meadows from amenity grass control sites, biodiversity of pollinators increased alongside that of flowering plants. However, such consistent relationships were not found when considering the 11 flower meadow sites alone (Table 4.2.), whereby the majority of the floral biodiversity metrics did not predict pollinator biodiversity. The exception to this was a significant, albeit weaker, relationship found between increasing floral richness and pollinator abundance within meadows sites (log_{10} pollinator abundance, $F_{1,9} = 8.73$, $p < 0.05$, $R^2 = 0.49$).

Table 4.1. Site-level median and range for ecological characteristics of flower meadows, the number of questionnaires completed, and measures of perceptions of ecological characteristics.

Variable	**Median (range)**			
Site treatment (number of sites)	**All sites (n = 17)**	**Control (n = 6)**	**Perennial (n = 5)**	**Annual (n = 6)**
Floral species richness (no. of flowering plant species)	22 (1-31)	3.5 (1-7)	24 (22-29)	24 (10-31)
Floral abundance	1,297 (0-15,856)	22 (0-186)	4,590 (759-856)	2,512 (827-9,951)
Floral diversity (Shannon's diversity index)	1.02 (0-2.35)	0.14 (0-1.00)	1.19 (0.84-1.62)	1.74 (0.57-2.35)
Proportion of flowering plant species native	0.86 (0.10-1.00)	1.00 (0.75-1.00)	0.92 (0.79-0.95)	0.44 (0.10-0.52)
Pollinator morphospecies richness (number of pollinator groups)	5 (0-7)	0.5 (0-2)	7 (5-7)	5 (3-6)
Pollinator total abundance	19 (0-118)	0.5 (0-4)	31 (12-91)	26.5 (8-118)
Pollinator morphospecies diversity (Shannon's diversity index)	1.20 (0-1.74)	0 (0-0.64)	1.59 (1.26-1.74)	1.24 (1.08-1.49)
Number of completed questionnaires	34 (24-45)	34 (24-40)	39 (33-45)	29.5 (28-36)
Perceived floral richness* (1-5)	2.85 (1.60-3.36)	1.89 (1.60-2.00)	3.05 (2.85-3.23)	2.89 (2.61-3.36)
Perceived floral proportion native* (0-1)	0.68 (0.50-0.81)	0.69 (0.50-0.74)	0.67 (0.55-0.81)	0.67 (0.56-0.74)
Perceived pollinator quality* (1-5)	4.05 (1.90-4.55)	2.74 (1.90-3.46)	4.05 (3.69-4.44)	4.38 (4.11-4.55)
Perceived colourfulness* (1-5)	2.76 (1.91-4.62)	2.23 (1.91-2.43)	2.76 (2.64-3.67)	4.19 (3.64-4.62)

*These scores were based upon scales constructed to represent respondents' perceptions of the characteristics of sites. For perceived floral richness 1 corresponded to *less than 5 species*, 2 to *6 to 10 species*, 3 to *11 to 20* species, 4 to *21 to 30 species,* and 5 to *more than 30 species*. For perceived proportion of native species, the scale ranged from 0 corresponding to *no native plants*, 0.25 to *about a quarter native*, 0.5 to *about half native*, 0.75 to *about three-quarters native*, and 1 to *all native plants*. Perceived quality for pollinators ranged from between 1 corresponding to *poor (not useful to pollinators)* and 5 to *excellent (very useful to pollinators*). Perceived colourfulness ranged between 1 corresponding to *very few colours* and 5 to *very many colours*.

Table 4.2. Linear regressions of relationships between measured floral and pollinator metrics within flower meadows. Showing associations across all sites (n = 17) and just meadows sites (n = 9). Bold font indicates significant relations at 95% confidence level.

	Floral biodiversity metric	**$\log_{10}$ (Floral abundance +1)**			**Floral richness**			**Floral diversity (Shannon's)**		
Sites (d.f)	Pollinator biodiversity metric	F	*p*	R^2	F	*p*	R^2	F	*p*	R^2
All 17 sites$_{(1,15)}$	$\log_{10}$ (Pollinator abundance +1)	**34.93**	**< 0.001**	**0.70**	**87.55**	**< 0.001**	**0.85**	**19.48**	**< 0.001**	**0.57**
	Pollinator richness	**40.11**	**< 0.001**	**0.73**	**67.50**	**< 0.001**	**0.82**	**10.83**	**< 0.01**	**0.42**
	Pollinator diversity (Shannon's)	**42.88**	**< 0.001**	**0.74**	**43.92**	**< 0.001**	**0.75**	**12.43**	**< 0.01**	**0.45**
Just meadows sites$_{(1,9)}$	$\log_{10}$ (Pollinator abundance +1)	0.00	0.967	0.00	**8.73**	**< 0.05**	**0.49**	1.33	0.279	0.13
	Pollinator richness	0.22	0.654	0.02	4.04	0.075	0.31	0.17	0.690	0.02
	Pollinator diversity (Shannon's)	0.01	0.913	0.00	0.59	0.463	0.06	0.65	0.442	0.07

Of the flowering plant species in the sites, 49 (63%) were native, ten (13%) were neophytes, seven (9%) were of unknown origin and three (4%) could not be identified to species level and could not be categorised (due to belonging to a taxonomic group containing species of various origin). The remaining nine (12%) species were archaeophytes, i.e. known to have become established members of the British flora before AD 1500 (Preston et al., 2002). The most frequently surveyed flowering plant species were the common native British wildflowers white clover (*Trifolium repens*), common daisy (*Bellis perennis*) and yarrow (*Achillea millefolium*), occurring in 12, nine and eight sites respectively. The most frequently encountered pollinator groups were honeybees (*Apis* spp.), other flies (flies of the order Diptera except those of the family Syrphidae), bumblebees (*Bombus* spp.) and hoverflies (of the order Syrphidae) (for a full list of species found at sites see Supporting Information S4.7.3.).

4.4.2. Estimates of floral richness

At a site level, the actual and perceived floral richness measures were significantly related, both when considering all sites (Figure 4.3A.), and when considering just meadow sites ($F_{1,9} = 9.11$, $p < 0.05$, $R^2 = 0.50$). However, analysis at this level only demonstrates if people, on average, could correctly identify whether sites were more or less species rich, and not how accurately they estimated the correct number of species. Using an index of accuracy to compare how closely people chose the correct category of species richness, we found that 51% correctly categorised the floral species richness of control sites. The majority of the remaining respondents in control sites (44%) overestimated species richness (Figure 4.3C). In both types of meadow sites, a majority of respondents underestimated species richness (annual, 55%; perennial, 70%). We found a significant difference in the distribution of people's accuracy in perceptions of species richness among types of meadows (Kruskal-Wallis χ^2_2 = 172.39, *p* < 0.001). Post-hoc tests confirmed a difference between control and meadows sites (control-annual, Dunn's Z = -10.10, *p* < 0.001; control-perennial, Z = 12.21, *p* < 0.001), but not between different meadows types (annual-perennial, Z = 1.90, *p* = 0.171).

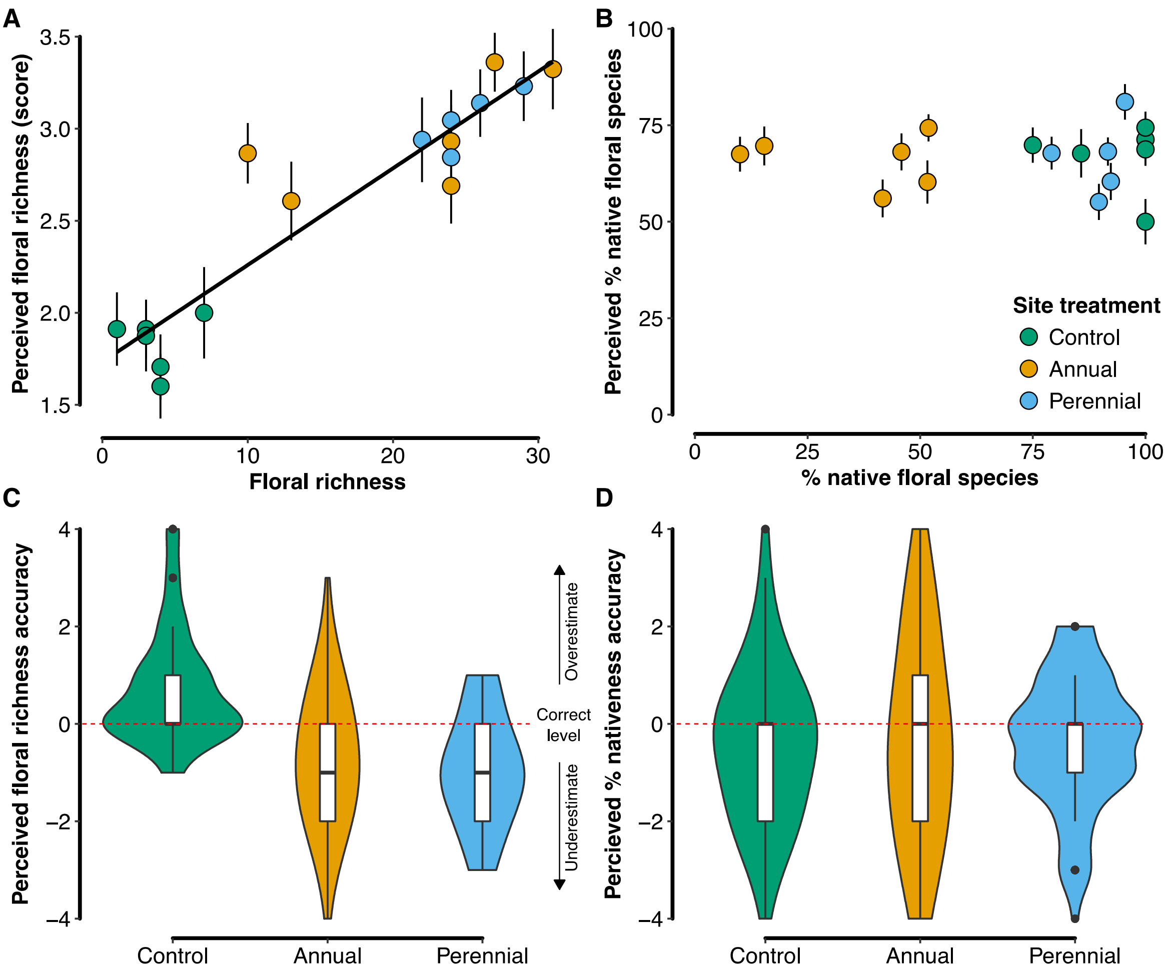

Figure 4.3. (A) Association between mean site-level perceived and actual floral richness ($F_{1,15}$ = 100.20, *p* < 0.001, R^2 = 0.87). The perceived richness score is the mean aggregate score on a five-point scale, where 1 = all respondents choose lowest category and 5 = all respondents choose highest category. (B) Association between mean site level perceived and actual % native species in sites ($F_{1,15}$ = 0.00, p = 0.96). The perceived percentage native score corresponds to 0 = all respondents thought there were no native floral species, 100% = all respondents thought all species native. Respondent accuracy at estimating floral richness (C) and percentage floral nativeness (D). Violin plots show the distribution of respondents' accuracy, whilst boxplots show the median and interquartile range, 0 = correct category, 4 = perceived was four categories higher than measured, -4 = perceived is four categories lower than measured.

4.4.3. Estimates of floral nativeness

There was no relationship between the actual percentage of native species and people's estimate of the percentage native species in sites. The mean perceived percentage of native species across sites was 68% (ranging from 50 – 81%, Figure 4.3B). However, control sites and perennial meadows contained predominantly native species (median 100% and 92% respectively), whilst annual sites contained a median of 44% native species. The majority of respondents underestimated the proportion of native floral species in control (59%) and perennial (62%) sites and overestimated in annual sites (66%) (Figure 4.3D). We therefore found a significant difference in the distribution of people's accuracy in estimating the percentage of native species between site treatments (Kruskal-Wallis χ^2_2 = 220.24, $p < 0.001$). Post-hoc tests confirmed a difference in the distributions of accuracy between control and annual sites (Dunn's test Z = -12.63, $p < 0.001$) and perennial and annual sites (Z = -13.22, $p < 0.001$). However, there was no difference in the distribution of accuracy between control and perennial sites (Z = 0.74, $p = 1.00$). This is due to the similar true percentage native floral species in these two treatments.

4.4.4. Estimating quality for pollinators

People's average site level estimate for pollinator quality predicted $\log_{10}$ pollinator abundance ($F_{1,15} = 23.42$, $p < 0.001$, $R^2 = 0.61$), morphospecies richness ($F_{1,15} = 19.46$, $p < 0.001$, $R^2 = 0.56$) and most strongly Shannon's diversity ($F_{1,15} = 25.61$, $p < 0.001$, $R^2 = 0.63$) across all sites. However, estimates of pollinator quality failed to predict the variation between just meadows sites (pollinator $\log_{10}$ abundance: $F_{1,9} = 0.01$, $p = 0.92$, $R^2 = 0.00$; morphospecies richness: $F_{1,9} = 1.37$, $p = 0.27$, $R^2 = 0.13$) and most strongly Shannon's diversity ($F_{1,9} = 0.41$, $p = 0.53$, $R^2 = 0.04$) across all sites.

4.4.5. Predictors of meadow colourfulness

The mean site level rating of colourfulness was predicted by $\log_{10}$ floral abundance ($F_{1,15} = 9.99$, $p < 0.01$, $R^2 = 0.36$), floral richness ($F_{1,15} = 8.45$, $p < 0.05$, $R^2 = 0.32$) and most strongly by floral diversity ($F_{1,15} = 20.78$, $p < 0.001$, $R^2 = 0.55$; Figure 4.4A). Floral evenness did not significantly predict people's rating of colour ($F_{1,15} = 4.10$, $p = 0.06$, $R^2 = 0.21$). However, when considering just meadows sites, none of these characteristics predicted colour rating (floral abundance: $F_{1,9} = 1.71$, $p = 0.22$, $R^2 = 0.16$; floral richness: $F_{1,9} = 0.71$, $p = 0.42$, $R^2 = 0.07$; floral diversity: $F_{1,9} = 3.28$, $p = 0.10$, $R^2 = 0.27$; floral evenness: $F_{1,9} = 4.45$, $p = 0.06$, $R^2 = 0.33$). People rated sites with a higher proportion of non-native species as more colourful, both across all sites ($F_{1,15} = 29.31$, $p < 0.001$, $R^2 = 0.64$; Figure 4.4B), and when just considering meadow sites ($F_{1,9} = 12.61$, $p < 0.01$, $R^2 = 0.54$).

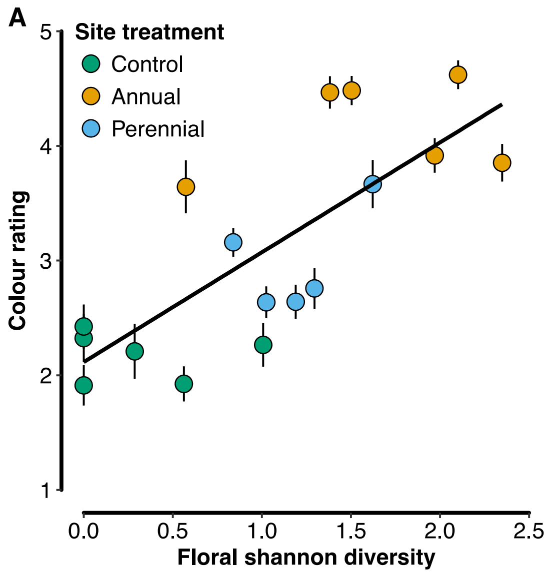

Figure 4.4. A. Association between mean site-level perceived colour ratings and floral Shannon diversity and B. the percentage of floral native species. The perceived richness score is the mean aggregate score on a five-point scale, where 1 = all respondents choose lowest category and 5 = all respondents choose highest category.

4.4.6. Individual, perceived and ecological characteristics effect on connectedness to nature

A subsample of our data was created for modelling predictors of connectedness to nature, by excluding individuals for which there was missing data for one or more of the explanatory variables and only including parks that included both a control and meadow site (n = 406). We constructed simple models including just the meadows characteristics (floral richness and nativeness), however this was no different to the results presented here when controlling for other potential explanatory variables (Table S4.7.3.). In our models of connectedness to nature (CNS) we found that neither of the tested measured biodiversity characteristics, floral richness and proportion floral nativeness, predicted CNS (Table 4.3.). Only one measure of people's perception of the character of meadows predicted connection to nature, which was people's estimate of the colourfulness of meadows (Table 4.3; Figure 4.5.). Measures of people's perceptions of floral richness and nativeness, and their accuracy at predicting these characteristics, did not predict CNS, and neither did their estimation of a site's quality for pollinators. Of the individual/socio-demographic characteristics tested, gender, walking a dog, ethnicity, and membership of a wildlife conservation or natural heritage organisation did not predict CNS. The more reported occasions a person spent in open spaces increased CNS. Finally, we found CNS to be predicted by age, respondents aged 45-54, 55-64 and 65+ all had a significantly higher CNS score than the reference group (18-24 year olds). However, this effect was not found amongst 25-34 or 35-44 year olds.

Table 4.3. Model parameters from General Linear Mixed Model (GLMM) of predictors of connectedness to nature (mean CNS[2]). Two random effects were included in the models to control for unobserved variation due to the study design, park identity and interviewer identity. Bold text indicates that the parameter estimate 95% confidence intervals do not cross zero.

Explanatory variables		**β**	**SE**	**LCI (2.5%)**	**UCI (97.5%)**	**RI**
Intercept		20.21	1.83	16.61	23.81	
Meadows characteristics						
Floral richness		-1.44	1.01	-3.43	0.55	0.44
Proportion floral native species		1.49	1.10	-0.68	3.66	0.41
Perceived meadows characteristics						
Perceived floral richness		-0.66	1.01	-2.64	1.33	0.16
Richness estimate accuracy		0.95	0.92	-0.86	2.75	0.26
Perceived proportion floral nativeness		-1.52	1.21	-3.89	0.85	0.38
Nativeness accuracy		1.54	1.21	-0.84	3.92	0.37
Pollinator quality estimate		0.04	0.42	-0.79	0.87	0.10
Colour estimate		**1.14**	**0.44**	**0.28**	**2.00**	**1.00**
Individual characteristics						
Gender	Male	-0.86	0.90	-2.62	0.90	0.24
Age category (vs. 18-24)	25 - 34	1.35	1.56	-1.72	4.41	**1.00**
	35 - 44	3.20	1.65	-0.05	6.45	
	45 - 54	**3.41**	**1.66**	**0.15**	**6.67**	
	55 - 64	**7.00**	**1.76**	**3.54**	**10.47**	
	65+	**7.55**	**1.78**	**4.06**	**11.04**	
Number of trips outdoors in last 7 days (log10+1)		**2.49**	**1.10**	**0.33**	**4.65**	**0.95**
Walking a dog		1.42	1.00	-0.55	3.38	0.47
Ethnicity	Non-white British	0.89	1.20	-1.46	3.25	0.17
Member of a conservation organisation		0.06	1.03	-1.98	2.09	0.10

β = averaged parameter estimates; SE = unconditional standard errors; LCI = Lower confidence interval (2.5%); UCI = upper confidence interval; RI = relative variable importance factor.

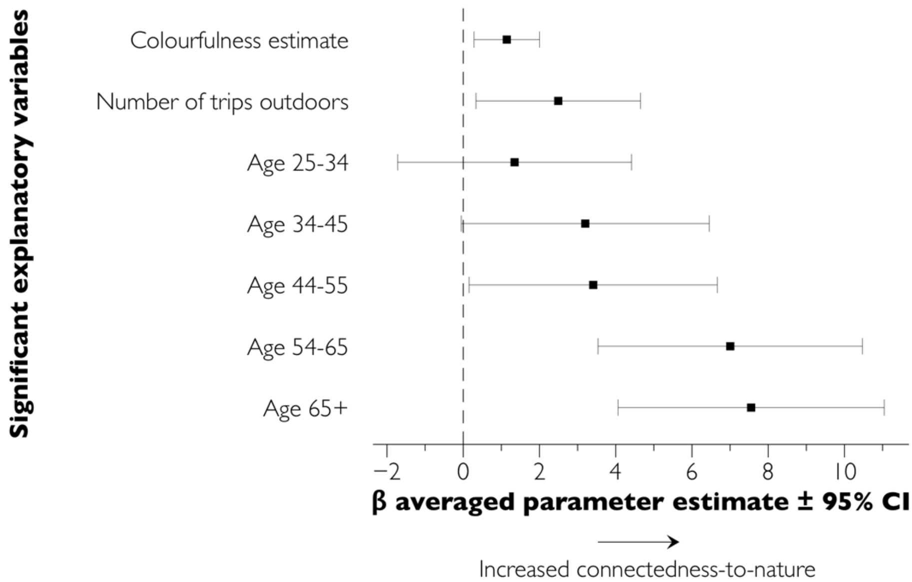

Figure 4.5. Significant predictors of connectedness to nature (mean CNS[2]) from General Linear Mixed Model (GLMM) (Table 4.3.).

4.5. Discussion

Using a novel quasi-experimental approach, we are able to understand further how urban greenspace users perceive biodiversity and whether this has any bearing on their connectedness to nature. Understanding how people perceive different characteristics of the natural world is important if we are to disentangle the relationship between biodiversity and the benefits people gain from interacting with nature (Pett et al., 2016). As was expected, the creation of flower meadows in greenspaces increased the floral richness of sites and therefore increased pollinator abundance and diversity. We found that people could broadly perceive species richness of plants, but could not perceive nativeness, and that people's estimates of quality of sites for pollinators predicted pollinator abundance and diversity. None of these factors influenced individuals' connectedness to nature, with the only site-level perceived factor to do so being site colourfulness.

4.5.1. Can people accurately estimate and perceive ecological characteristics?

People could broadly perceive differences in floral species richness between sites but overestimated sites with a lower species richness (control sites) and underestimated the species richness of meadows sites with higher species richness. Whilst some previous studies have found that people could broadly perceive differences in low/high biodiversity (Fuller et al., 2007; Lindemann-Matthies and Marty, 2013; Qiu et al., 2013), others have not found this (Dallimer et al., 2012; Shwartz et al., 2014). Our findings are similar to Lindemann-Matthies et al. (2010a) who also found in experimentally manipulated meadow plots, that people overestimated low richness and underestimated high richness. People express a preference for higher species richness and find this more aesthetically pleasing, and therefore by not accurately perceiving plant communities, people's evaluations of sites could be biased.. For example, if people consistently underestimate sites of higher biodiversity, this could lead them to attach less value to sites that are ecologically valuable. We also found that people could not estimate the proportion of native species in a site, this is despite expressing a preference for more native species (see Chapter 5). People may have the expectation that non-native planting will look 'exotic' (Lindemann-Matthies, 2016), and this may have contributed to people not recognising the annual meadows in our study as containing a lower proportion of native species.

Planting urban meadows increases the ecological value of sites for pollinators, and we found that people were able to perceive that meadows were of a higher quality for pollinators than the control sites. Although people could distinguish these broad differences, people could not distinguish the subtler differences between meadows sites alone. We also found that people's rating for colour was higher for meadows sites, and therefore was related to floral abundance, richness and diversity, but these ratings were not significantly higher due to ecological characteristics when just considering meadows sites. Interestingly however, we found that meadows that contained a higher proportion of non-native species (annual sites) were rated as most colourful. Unlike Lindemann-Matthies et al. (2010a) we did not find this difference in aesthetic assessment to be related to the evenness of plants in the meadow. People therefore found annual meadows to be more colourful but did not realise that they contained a higher proportion of non-native species.

4.5.2. Which ecological and individual factors predict people's state of connectedness to nature in greenspaces?

We found no relationship between the actual or perceived ecological characteristics of flower meadows and individuals' connectedness to nature. The only site-level characteristic that was significantly related to connectedness to nature was people's ratings of the colourfulness of sites. Therefore, although people could broadly perceive differences between meadows, these ecological characteristics did not influence people's state of connectedness to nature. Similarly, researchers in Australia found little association between ecological characteristics in neighbourhoods, and people's levels of connectedness to nature, and a stronger association between demographic factors and connectedness to nature (Luck et al. 2011). However, connectedness to nature can vary due to experiencing sites of varying environmental quality, for example between broadly defined natural and urban settings (Mayer et al., 2009). Wyles et al. (2017) found that people recalled greater connectedness to nature following visits to sites of a higher environmental quality (defined as sites with protected/designated status). These both differ in scale from our study, comparing between people's evaluation based on entire sites rather than measuring connectedness to nature based on narrower ecological characteristics. It may therefore be that the differences in environmental quality associated with subtle changes, such as the species richness of one group, may be less important than factors associated with whole sites, which we did not observe in this study. It is notable that people who rated sites as more colourful had a higher connectedness to nature, but the direction of causality is unclear. It could be that individuals who have a higher connectedness to nature are more likely to perceive areas as more colourful, or conversely that perceiving a greater colourfulness leads to a higher connectedness to nature.

We found individuals' characteristics to be related to their connectedness to nature and people who reported to take more trips outdoors had a significantly higher connectedness to nature. Similarly, people who engage in more 'appreciative outdoor recreation' have also previously been found to have a higher connectedness to nature than those who do not (Wolsko and Lindberg, 2013) and a related construct (nature relatedness) has been found to correlate with the time spent in nature and outdoors (Nisbet et al., 2009). However, it is worth noting that some studies have not found this association (Ernst and Theimer, 2011; Zylstra et al., 2014). We also found that connectedness to nature was higher among older age groups, similar to Luck et al. (2011) and Cervinka et al. (2012). However, whether this is a generational difference, or that people become more connected to nature over time could only be investigated more thoroughly via longitudinal studies. We did not find a difference between genders in our study, unlike previous studies (Cervinka et al., 2012; Haluza et al. (2014), but this may be due to controlling for so many other variables in our models.

4.5.3. Implications and conclusions

We found that people could broadly perceive differences in some biodiversity characteristics, such as species richness and the quality of sites for pollinators. However, people could not perceive other potentially important characteristics such as the nativeness of plants. These findings further our understanding of how people perceive biodiversity and the indicators that people associate with ecological quality. Our findings also have implications for the planning of urban landscapes that aim to meet multiple goals of achieving aesthetic appreciation and biodiversity conservation. The results suggest that people associate colourful meadow planting with higher levels of species richness, and that colourfulness is associated with a higher connectedness to nature. Therefore, appropriately designed urban meadows, and colourful planting more generally, may be a win-win intervention for urban conservation in providing benefits for pollinators and people. More broadly, it is likely that beyond the ecological characteristics used to measure communities of species, certain traits belonging to individual species such as colour and size may be more noticeable to people and therefore be the key to further unpicking the relationship between biodiversity and the delivery of cultural ecosystem services.

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4.7. Supporting Information

Appendix S4.7.1. Seed mixes planted at perennial and annual meadow sites.

Perennial seed mix (Special Pollen and Nectar Wild Flower mix EN1F; Emorsgate Seeds, 2017):

Scientific name	English common name
Achillea millefolium	Yarrow
Centaurea nigra	Common Knapweed
Centaurea scabiosa	Greater Knapweed
Daucus carota	Wild Carrot
Echium vulgare	Viper's Bugloss
Eupatorium cannabinum	Hemp-agrimony
Galium verum	Lady's Bedstraw
Knautia arvensis	Field Scabious
Leontodon hispidus	Rough Hawkbit
Leucanthemum vulgare	Oxeye Daisy
Lotus corniculatus	Birdsfoot Trefoil
Malva moschata	Musk Mallow
Origanum vulgare	Wild Marjoram
Primula veris	Cowslip
Prunella vulgaris	Selfheal
Pulicaria dysenterica	Common Fleabane
Ranunculus acris	Meadow Buttercup
Reseda lutea	Wild Mignonette
Rhinanthus minor	Yellow Rattle
Silene dioica	Red Campion
Stachys sylvatica	Hedge Woundwort
Trifolium pratense	Wild Red Clover
Vicia cracca	Tufted Vetch

Annual seed mix (Rainbow Annuals; Rigby Taylor, 2017):

Scientific name	English common name
Calendula officinalis	Pot marigold
Centaurea cyanus	Cornflower
Coreopsis picta	Picta tickseed
Coreopsis tinctoria	Plains Coreopsis
Cosmidium burridgeanum	Cosmidium
Cosmos bipinnatus	Cosmos bipinnatus
Eschscholzia californica	Californian Poppy
Gypsophila elegans	Showy Baby's Breath
Linum grandiflorum	Red flax
Lobularia maritima	Sweet alyssum
Malcolmia maritima	Virginia Stock
Papaver rhoeas	Corn/English Poppy

Note, one site, Inch Park, in Edinburgh contained a slightly different 'Cornfield annual' seed mix.

Table S4.7.1. Site treatments within parks, number of completed questionnaire and response rates.

City	Park	Treatment/seed mix	Total number completed questionnaires	Response rate (%)
Bristol	Horfield Common	Perennial	33	41.77
	Horfield Common	Control	34	47.22
	St. Andrews	Annual	30	36.14
	St. Andrews	Control	34	37.78
	Gores Marsh Park	Annual	28	35.90
Edinburgh	Pilrig	Perennial	44	32.12
	Pilrig	Control	41	33.61
	St Marks	Perennial	45	30.00
	Inch Park	Cornfield Annual	36	26.09
	Inch Park	Control	40	34.48
Leeds	Stanhope Recreation Ground	Perennial	36	54.55
	Burley Park	Perennial	39	53.42
	Burley Park	Control	34	44.74
	Rodley Park	Annual	29	64.44
	Middleton Park	Annual	34	58.62
	Middleton Park	Control	24	48.00
	King Lane	Annual	29	51.79

Appendix S4.7.2. Pollinators identified in the field were grouped as followed:

- Bumble bees (*Bombus*) incuding:
- White tailed bumble bees (*Bombus terrestris, Bombus lucorum* and *Bombus hortorum*)
- Brown bumble bees (*Bombus pascuorum*)
- Red tailed bumble bees (*Bombus lapidarious* and *Bombus pratorum*)
- Tree bumble bee (*Bombus hypnorum*)
- Honey bees (*Apis sp.*)
- Other bees (non *Bombus sp.* or *Apis sp.*)
- Butterflies and moths (*Lepidoptera*)
- Hoverflies (*Syrphidae*)
- Other flies (*Diptera*)
- Other insects (including beetles, bugs, social wasps and solitary wasps)

Table S4.7.2. Socio-demographic and economic characteristics of the final sample and comparison to population statistics (Eurostat, 2017). Two-tailed G-tests of goodness-of fit show where the sample is different in proportion to the general population. *Note where sample is disaggregated figures may not sum to the total in each country due to a small number of respondents who chose to not disclose gender, age, ethnicity or income

City		**Leeds**			**Bristol**			**Edinburgh**		
		Sample*	% sample	City % over 18	Sample*	% sample	City % over 18	Sample*	% sample	City % over 18
Total (N)	589	225			159			205		
Gender	Male	98	43.56	49.06	75	47.17	49.93	96	46.83	48.70
	Female	127	56.44	50.95	84	52.83	50.07	109	53.17	51.30
G-test		$G_{(2,1)} = 2.73$, $p = 0.098$			$G_{(2,1)} = 0.49$, $p = 0.486$			$G_{(2,1)} = 0.29$, $p = 0.592$		
Age group	18 – 24	30	13.33	13.14	17	10.69	13.74	16	7.84	11.85
	25 – 34	45	20.00	19.71	35	22.01	24.21	40	19.61	22.82
	35 – 44	40	17.78	16.95	36	22.64	17.41	35	17.16	17.21
	45 – 54	44	19.56	16.82	28	17.61	15.31	38	18.63	16.46
	55 – 64	27	12.00	13.27	26	16.35	11.91	32	15.69	13.09
	65 and over	39	17.33	20.11	17	10.69	17.41	43	21.08	18.58
G-test		$G_{(2,5)} = 2.24$, $p = 0.814$			$G_{(2,5)} = 11.44$, $p < 0.05$			$G_{(2,5)} = 6.31$, $p = 0.277$		
Ethnicity	All white	204	91.89	85.1	153	96.23	83.97	186	90.73	91.8
	All non-white	18	8.11	14.9	6	3.77	16.03	19	9.27	8.2
G-test		$G_{(2,1)} = 9.42$, $p < 0.01$			$G_{(2,1)} = 24.33$, $p < 0.001$			$G_{(2,1)} = 0.30$, $p = 0.584$		
Income group	Up to £5,199	8	4.65		2	1.50		12	6.45	
	£5,200 - £10,399	10	5.81		8	6.02		20	10.75	
	£10,400 - £15,599	14	8.14		16	12.03		18	9.68	
	£16,000 - £20,779	17	9.88		9	6.77		29	15.59	
	£20,800 - £25,999	19	11.05		9	6.77		21	11.29	
	£26,000 - £31,199	23	13.37		26	19.55		23	12.37	
	£31,200 - £36,399	21	12.21		13	9.77		20	10.75	
	£36,400 - £51,999	30	17.44		19	14.29		24	12.90	
	£52,000 and above	30	17.44		31	23.31		19	10.22	

Appendix S4.7.3. All plant species and genera sampled within sites

Achillea millefolium
Bellis perennis
Calendula officinalis
Capsella bursa-pastoris
Centaurea cyanus
Centaurea nigra
Cerastium fontanum
Cirsium arvense
Cirsium vulgare
Coreopsis tinctoria
Cosmidium burridgeanum
Cosmos bipinnatus
Daucus carota
Echium vulgare
Epilobium sp.
Erysimum cheiri
Eschscholzia californica
Galeopsis tetrahit
Galium album
Galium mollugo
Galium verum
Glebionis segetum
Gypsophila elegans
Hieracium pilosella
Hypochaeris radicata
Hyssopus officinalis
Iberis amara
Iberis umbellate
Knautia arvensis
Lamium album
Lapsana communis
Leontodon hispidus
Leucanthemum vulgare
Linum grandiflorum
Lobularia maritima
Lotus corniculatus
Malcolmia maritima
Malva moschata
Malva sylvestris
Matricaria discoidea
Medicago lupulina
Myosotis sp.
Nigella damascena
Origanum vulgare
Papaver rhoeas
Persicaria maculosa
Phacelia campanularia
Phacelia tanacetifolia
Plantago lanceolata
Plantago major
Polygonum aviculare
Prunella vulgaris
Pulicaria dysenterica
Pulicaria sp.
Pulicaria vulgaris
Ranunculus acris
Ranunculus repens
Reseda lutea
Scorzoneroides autumnalis
Senecio jacobaea
Senecio vulgaris
Silene dioica
Silene latifolia
Sinapis arvensis
Sisymbrium officinale
Sonchus asper
Sonchus oleraceus
Stachys sylvatica
Stellaria media
Taraxacum agg.
Trifolium dubium/campestre
Trifolium pratense
Trifolium repens
Tripleurospermum inodorum
Veronica persica
Vicia cracca
Vicia hirsuta
Viola tricolor

Table S4.7.4. Model parameters from an unadjusted General Linear Mixed Model (GLMM) including just ecological predictors of connectedness to nature (mean CNS[2]). Two random effects were included in the models to control for unobserved variation due to the study design, park identity and interviewer identity.

Explanatory variables	**β**	**SE**	**LCI (2.5%)**	**UCI (97.5%)**	**RI**
Intercept	26.51	1.01	24.53	28.49	
Meadows characteristics					
Floral richness	-0.05	0.95	-1.92	1.81	0.21
Proportion floral native species	0.05	0.95	-1.81	1.92	0.21

β = averaged parameter estimates; SE = unconditional standard errors; LCI = Lower confidence interval (2.5%); UCI = upper confidence interval; RI = relative variable importance factor.

Appendix S4.7.4. Supporting information references

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Chapter 5. Public preferences for the creation of pollinator-friendly wildflower meadows in urban greenspaces: a semi-experimental cross-city comparison

Due for submission to *Biological Conservation*.

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5.1. Abstract

Greenspaces can provide key habitats and resources for biodiversity in urban areas, and are known to improve the health and well-being human populations. Yet, key knowledge gaps exist with regards to the specific characteristics of biodiversity that underpin the delivery of these cultural ecosystem services, and the extent to which these are valued by members of the public. We used the stated preference non-market analysis technique of choice experiments, as a novel approach to understanding people Willingness To Pay (WTP) for wildflower meadows as a biodiversity intervention in urban greenspaces. This was delivered via a questionnaire conducted *in situ* with 563 respondents (N) in 17 sites across three cities in the UK. We found greenspace users to be supportive of efforts to create urban meadows for pollinator conservation in their nearby greenspaces. People had a WTP for more species rich, native, colourful and more pollinator friendly wildflower meadows. Preferences for colour and quality for pollinators were greater among respondents who reported a higher connectedness to nature. WTP was relatively similar regardless of city, or whether people were stood next to a wildflower meadow at the time, or gender. The relative magnitude of these preferences has implications for the planning and design of biodiversity in urban greenspaces and these findings suggest that such interventions could present a win-win scenario for people and biodiversity conservation.

5.2. Introduction

More than half of the world's population now live in cities, and this proportion is rising (UNDP, 2011). In developed regions, this percentage is much higher, such as in the UK where around 90% of people now live in urban areas. Alongside the pressures that urbanisation places on biodiversity (Grimm et al., 2008; Aronson et al., 2017), rapid urban development presents challenges for cities' human inhabitants, through a reduction in ecosystem services and a lack of opportunity for people to interact with nature and in return gain benefits (Turner et al., 2004; Soga and Gaston, 2016). Yet, there is a substantial body of evidence on the importance of interacting with nature in people's local environment for their health and well-being (Keniger et al., 2013; Hartig et al., 2014; Gascon et al., 2015;

Sandifer et al., 2015; Cox et al., 2017). Therefore, the design of urban areas, which integrate nature and natural features, can serve the purpose of reducing the societal burden of ill health, alongside delivering multiple other social goods. As urban land cover is forecast to triple between 2000 and 2030, many of the city landscapes that will exist in 2030 have yet to be built (Seto et al., 2012). This presents an opportunity for policy makers and planners to integrate more natural features into the design of future, and regenerated, urban landscapes, to simultaneously address these multiple interlinked challenges (Artmann et al., 2017).

Stakeholders and policy makers interested in urban planning are increasingly working towards achieving win-win (or synergistic) scenarios, where, multiple ecosystem services can be delivered by one site, while efficiently maximising financial resources (Hansen and Pauleit, 2014). However, as with any multifunctional land use, there may be trade-offs between different stakeholder values and goals in the design and management of urban greenspaces, which need to be reconciled (Eigenbrod et al., 2009; Maes et al., 2012). For instance, some greenspace users may prefer short amenity grass for recreation, which generally tends to be of low value to biodiversity. Social demand and access to the benefits of green infrastructure must be understood if multifunctionality is to be realised.

Like in many human dominated landscapes, practical management interventions in urban areas need to balance human needs and perceptions, alongside the goal of maintaining ecological processes (Aronson et al., 2017). Yet, the concepts used by scientists in describing ecological quality may not correspond with the cultural concepts of aesthetic quality valued by the public, or likewise describe the conditions that lead to measureable changes in health or well-being (Pett et al., 2016). Understanding where these concepts align or diverge is important in order to create effective urban green infrastructure and nature-based solutions. One increasingly popular form of ecological intervention in urban greenspaces is the introduction of flower meadows for pollinators. Accordingly, in this study we focused on traits of sown urban meadows that may be of value to urban greenspace users, and/or important due to their ecological value. Previous studies on preferences for different vegetation types, and the characteristics which influence aesthetic appreciation, indicate that features which are typical of urban meadows, such as colour and structural and floral diversity are often preferred (e.g. Hands and Brown, 2002; Lindemann-Matthies and Bose, 2007; Hoyle et al., 2017a; Southon et al., 2017). It is important to understand and represent public preferences and attitudes towards environmental interventions, especially when potentially implemented on public land and with public funds.

We used the stated preference non-market analysis technique of choice experiments, which is increasingly used in environmental decision making (Hanley and Barbier, 2009), as a novel approach to understanding preferences for biodiversity in urban greenspaces. This method allowed us to disentangle societal preferences for a conservation intervention and identify where trade-offs may occur. Here we address three interrelated research questions in regard to urban meadows: (i) Are people willing to pay for the creation of urban meadows in public greenspaces?; (ii) Which characteristics of urban meadows do people have a preference for?; and, (iii) Do these preferences change dependent on the characteristics of individuals (e.g. gender, connectedness to nature) or population/environmental factors (e.g. city, being in the vicinity of an urban meadow)?

5.3. Methodology

5.3.1. Study system

Mown amenity grass, managed primarily for recreation, is one of the most common forms of urban greenspace, especially in temperate regions (Irvine et al., 2009; Forestry Commission, 2006). These areas support a relatively low invertebrate diversity and abundance due to their low plant diversity, are typically dominated by a few grass species (Dover, 2015) and require regular mowing, which limits structural diversity (Garbuzov et al., 2015). Due to the decreasing financial resources available for urban greenspace management (Heritage Lottery Fund, 2016), there has been increased interest in vegetation types which require less intensive management, and are therefore less costly than amenity grass (Klaus, 2013), such as urban wildflower meadows (hereafter urban meadows). Recent research demonstrates the potential of urban areas to support a high diversity and abundance of native pollinators (Osborne et al., 2008; Baldock et al., 2015). Increasing the number of flowers in an area is one measure that could increase the value of cities for pollinator conservation (Hall et al., 2017) and planting urban meadows, containing beneficial flowers for insect pollinators, has become increasingly popular in urban areas in the UK in recent years (e.g. River of Flowers, 2013; Buglife, 2017). Urban meadows are of interest not just because of potential cost savings, or the refuge they provide for pollinators, but also because of their potential to offer cultural services for people, such as aesthetic enjoyment and the associated benefits of interacting with nature. However, the extent to which people value various characteristics of urban meadows, and their potential to provide these cultural benefits, is relatively unknown. This study used a wider existing multi-city ecological experiment taking place in the UK (Urban Pollinators Project UPP, 2017). As part of the UPP, meadows containing nectar- and pollen-rich plant species were established in 2012 and 2013 in areas of amenity grass in UK cities to assess the effects of sown flower meadows for insect pollinators in urban areas. This provided an opportunity for us to study the responses of people to this intervention as a natural experiment.

5.3.2. Site selection

We selected three cities involved in the UPP, namely Bristol, Leeds and Edinburgh (Figure 5.1.). These spanned the latitudinal gradient of the UK and were broadly comparable, all being among the top 11 most populous city regions in the UK (ONS, 2016) and included parks in more/less affluent parts of each city. Meadows sown in the UPP were 300 m^2 in size and mostly rectangular in shape. Two types of urban meadow were established as part of the UPP, comprising of different commercially available seed mixes and requiring different management intensities. With perennial meadows containing predominantly native, and annual meadows containing a mix of native and non-native wildflowers. These meadows types also varied visually, containing a different composition of colours, and may therefore vary in their value to people (see Chapter 4 for further details). To represent a range of meadow types, we selected 17 sites within 11 public parks in the three cities, on the basis of sites being publically accessible and therefore likely to receive sufficient numbers of visitors. All selected sites were surrounded by residential areas and were visited by local people. Six greenspaces included both a meadow and a paired 'control' site (i.e. an area of amenity grass that had not been turned into a flower meadow). This was to allow for a comparison between people's preferences for different meadows types and the values they attributed to them. Control meadows were marked out to show the area where an urban meadow would hypothetically be and were placed at a suitable distance, so that the planted meadow was not visible. In some smaller parks this was not possible, as park users would be able to see the meadows in control locations, so no control was included. We therefore had three quasi-experimental site treatments (i) perennial meadows (ii) annual meadows and (iii) control meadows constituting of equally sized amenity grass areas.

5.3.2. Choice experiment approach

Choice experiments rely on the assumption that any good can be viewed as a bundle of characteristics, known as attributes, and that people will choose a good with the characteristics that offer them the highest utility (i.e. satisfy their individual needs or wants) (Lancaster, 1966). When observing people's choices between goods with different bundles of characteristics, we can estimate their relative preferences for the individual characteristics of a good by applying Random Utility Theory (McFadden, 1974). Participants in a choice experiment choose their preferred option from a number of described alternatives, which vary in their characteristics. People therefore express their preferences through trade-offs, allowing estimation of the marginal utility for individual characteristics, which would otherwise only be considered in aggregate (Adamowicz et al., 1998). If monetary cost is included in the choices (e.g. to finance the changes to the particular characteristics of a good), this allows a 'Willingness To Pay' (WTP) metric to be derived for each individual change in a characteristic (the 'attribute levels'). Inversely 'Willingness To Accept' (WTA) represents the amount of hypothetical compensation that the respondent would need to receive, to be satisfied with a good they find undesirable (for description of the specification of choice models see Supporting Information 5.7.1.).

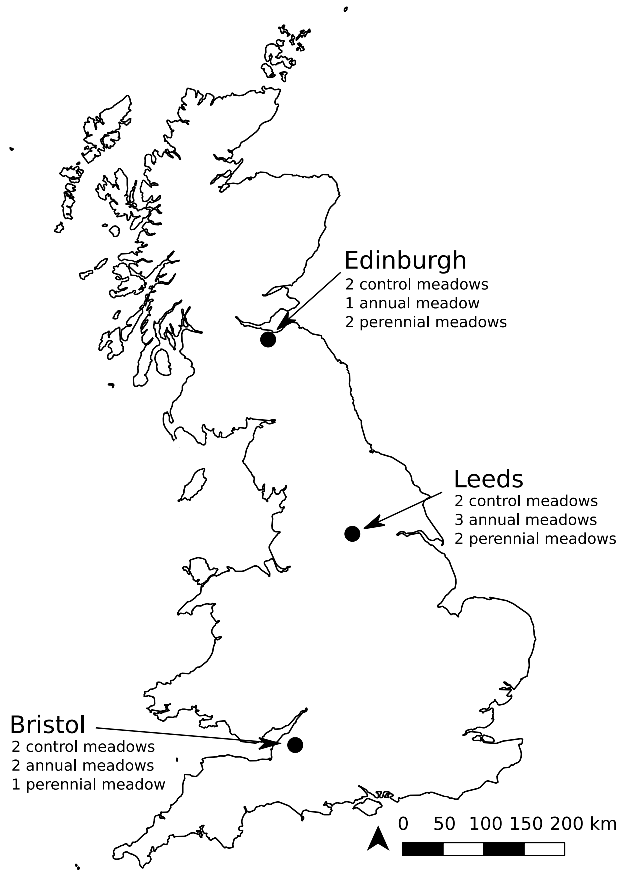


Figure 5.1. The location of the three British cities and number of study sites sampled in each city.

5.3.3. Choice experiment attributes

The selection of attributes in our choice experiment was based on the characteristics of urban meadows that may be of value to the public. The development of choice scenarios was informed by estimates of the changes to characteristics that an amenity grass site could display after the creation of urban meadows. Biodiversity has previously been found to have value to people (Christie et al., 2006; Morse-Jones et al., 2012; Dallimer et al., 2014). To investigate if this value is present in people's assessments of urban meadows, we developed an attribute representing the change in plant species richness associated with the creation of a meadow. We developed a quantitative scale, based upon the range of increase in the number of plant species from the creation of a meadow found in earlier UPP work (Table 5.1.).

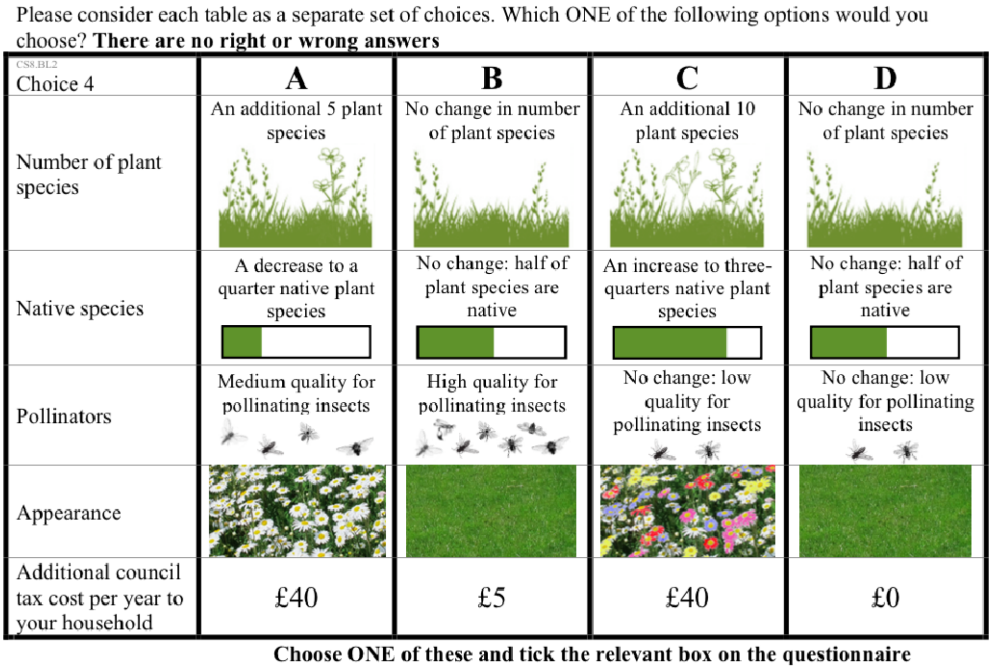
To measure if there was a public preference towards native or non-native planting, we included the proportion of native species within the choice set (Table 5.1.). Studies of people's attitudes and preferences towards species based on their nativeness have so far found varying results in different contexts (Fischer et al., 2011; Kendal et al., 2012; Hoyle et al., 2017b). Although there is a prevailing opinion that urban green infrastructure should consist of native planting, some ecologists and planners are questioning this view (Davis et al., 2011; Hitchmough, 2011). This is in light of growing evidence that non-native plants may provide valuable resources for pollinators, sometimes extending beyond the flowering season of native plants, or that they will become more suitable than native species due to a changing climate (Garbuzov and Ratnieks, 2014; Hanley et al., 2014; Salisbury et al., 2015 Hicks et al., 2016).

The values people attach to the sowing of an urban meadow may come directly from a desire to provide habitat for pollinators, especially due to recent concerns about pollinator declines. The extent to which people value and are aware of pollinators and pollination services has been identified as a knowledge gap (Hanley et al., 2015). Constructing a linear quantitative scale for pollinators was not possible, as it is difficult to accurately predict the abundance or diversity of pollinators in a given meadow, even with ecological training and expertise. It was therefore inappropriate to use such a scale with the general public and so for simplicity and clarity, we used an ordinal scale of 'quality for pollinating insects', ranging from low to high (Table 5.1.).

The final attribute, appearance, was chosen to investigate how people's preferences changed due to variations in floral colour. Previous studies have found a preference among people for brightly coloured flowers (Lindemann-Matthies and Bose, 2007, Junge et al., 2009). The visual appearance of an urban meadow varies widely due to a variety of factors, such as the shape and size of flowers, the height and structure of planting, and the proportion of flower cover. To control for these other factors, in order to focus only on colour, we devised attribute levels by digitally manipulating a photograph of a perennial meadow containing white flowers (*Leucanthemum vulgare*). Therefore, our scale ranged from amenity grass, a meadow containing just white flowers, a meadow containing three colours and finally a meadow containing five colours (Table 5.1.). These categories broadly represented the variation in meadow colourfulness found in the established meadows planted as part of the UPP.

The financial cost associated with choices was specified as increases to the householder's annual council taxation bill. Council tax is a local taxation system used in England and Scotland for council services, such as the maintenance of parks. Urban parks in the UK do not charge entrance costs, and therefore taxation is an appropriate payment vehicle. The scale used was adapted from a previously tested scenario involving changes in the number of species in public greenspaces in a UK city (Dallimer et al., 2014). To mitigate the influence of bias in our WTP estimates due to the hypothetical nature of the choice experiment ('hypothetical bias'; Carlsson et al., 2005), we included a section prior to the choices, which prompted respondents to think carefully about the additional council tax payment in relation to their household income (known as a 'cheap talk'). In addition, we included a 'budget reminder' and 'opt-out reminder', informing respondents that additional council tax payments will reduce their spending on other things in their everyday life, and instructing them to choose the opt-out alternative if they found the proposed choices too expensive.

The attributes chosen for the choice cards (described as the change from the current situation) were: number of plant species, proportion of native species, quality for pollinating insects, appearance, and a related cost described as an additional increase in council tax per year to the respondent's household (Table 5.1., Figure 5.2.). Each set of choices included four options, where one was always fixed as 'no change', through which the respondent could opt out with no change in tax payment. The current situation was described as containing six plant species, half of which are native and providing few resources for pollinating insects. This was visually represented by a photograph of an area of amenity grass. The questionnaire was piloted with 16 people in park areas that have urban meadows, to examine public comprehension of the descriptions of the attributes. Piloting confirmed that our payment vehicle, range of costs and presentation of the attributes and choices was acceptable to members of the public.

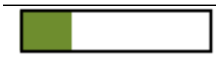
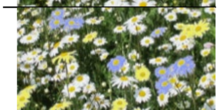

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS8.BL2 Choice 4	A	B	C	D
Number of plant species	An additional 5 plant species	No change in number of plant species	An additional 10 plant species	No change in number of plant species
Native species	A decrease to a quarter native plant species	No change: half of plant species are native	An increase to three-quarters native plant species	No change: half of plant species are native
Pollinators	Medium quality for pollinating insects	High quality for pollinating insects	No change: low quality for pollinating insects	No change: low quality for pollinating insects
Appearance				
Additional council tax cost per year to your household	£40	£5	£40	£0

Choose ONE of these and tick the relevant box on the questionnaire

Figure 5.2. Example of a choice card from the questionnaire. Respondents were asked to choose one column from A-D in each choice card. D always represented the ‘no change’ option with no associated tax increase.

Table 5.1. Attributes and options of change in the urban wildflower meadow characteristics used in choice experiment.

Attribute	Levels *(no change option)*	Illustrations	Questionnaire description
Number of plant species	*No change in the number of plant species*		"In the UK, the government has made commitments to protect the number of species of plants and animals in the country. Grassy areas within parks may include a large variety of plant species, so could contribute to this goal if suitably managed."
	An additional 5 plant species		
	An additional 10 plant species		
Proportion of native species	*No change: half of plant species are native*		"Native species are animals or plants that occur naturally in an area. Non-native species are those which do not occur naturally in an area, and have been introduced by people (e.g. Japanese knotweed and grey squirrels are both non-native species that were introduced to the UK by humans). Non-native species can sometimes have negative impacts on native species, as well as impacting on people (e.g. Japanese knotweed can cost householders a considerable amount of money to remove from their property)."
	A decrease to a quarter native plant species		
	An increase to three-quarters native plant species		
Quality for pollinating insects	*No change: low quality for pollinating insects*		"In the UK, pollinating insects such as bees and hoverflies are in decline. Many wild flowers, vegetables, fruits and other crop plants depend on insect pollinators to reproduce. City parks and greenspaces have the potential to support large numbers of insect pollinators if suitably managed."
	Medium quality for pollinating insects		
	High quality for pollinating insects		
Appearance (note: just the photographs were shown here and no text)	*No change (grass)*		"Planting flowers can alter the appearance of grassy areas within parks, for example by making the area more colourful."
	White flowers		
	White, yellow and blue flowers		
	White, yellow, blue, pink and red flowers		
Cost (additional council tax cost per household per year)	*£0* £5 £10 £20 £40 £60		"Choices may be paid for through an increase in council tax. You may, therefore, prefer not to see any changes, as this will not cost you anything and the management of the grassy area will remain the same."

A statistically efficient choice experiment design was created using software Ngene (version 1.1.2; 2014) consisting of twelve choice tasks. The design was made more efficient by the inclusion of prior estimates of the parameters (i.e. people's relative preferences for different attribute levels) from our pilot sample. The ex-ante d-error for the final multinomial model was 0.1076, which is acceptable (Scarpa and Rose, 2008). Completing a large number of choices is cognitively demanding (Weller et al., 2014), and so to reduce the time burden of completing the questionnaire, we created two experimental blocks. Consequently, each respondent only had to complete one set of six choice sets. We alternated the allocation of experimental blocks to respondents, to achieve a near equal number of completed choice sets for each site.

Following standard practise, Likert-style questions were placed prior to the choice experiment exercise (Bateman et al., 2002). To investigate if individuals' emotional connection to the natural world influenced their preferences, we employed the seven-point, fifteen item, adapted Connectedness to Nature Scale (CNS), directed at measuring the connection respondents were 'presently experiencing' (Mayer et al., 2009). Items to collect the socio-economic background of respondents, such as age, household income, gender and ethnicity were placed after the choice experiment.

5.3.4. Data collection

Questionnaires were delivered *in situ* next to the urban meadows or control sites by six trained interviewers, during the peak flowering season of July and August 2014. To represent the range of people using greenspaces, each site was visited at least once during four timeslots; weekdays and weekends, and during daytime and early evenings. A consistent method of guiding respondents through the questionnaire was used and prior to starting the questionnaire, each participant was given assurance of anonymity. Respondents were asked to provide verbal informed consent and made aware that their participation was voluntary and that no compensation would be provided. All respondents were over 18 and we received ethical approval from the University of Kent before proceeding with the study. Our sample was non-random and self-selected (i.e. we did not interview people who did not visit the greenspaces). Nevertheless, our objective was to represent and understand the perceptions of current greenspace visitors and not to characterise the difference between visitors and non-visitors.

5.3.5. Analysis

G-tests of goodness of fit were used at α level 0.05 to assess if/where the socio-demographics of the sampled respondents differed in their distribution from the city population in 2014, according to Eurostat (2017). We corrected the sample for serial non-participation by excluding respondents who chose the 'no change' option for all choice cards and whose answers to a follow up question indicated that they were protesting against the questionnaire or the payment vehicle (see Supporting Information 5.7.2.). All preference parameter estimates should be interpreted as the utility/disutility of a change from the level of the 'no change' option to the specific variable level. These no change options are referred to as Alternative Specific Constants (ASC) in the economic literature. Random parameter models were used to allow for heterogeneity in preferences to be considered in the analysis, by assuming a probability distribution around the estimated preference parameters (McFadden and Train, 2000; Supporting Information 5.7.1.). Modelling with this approach also resulted in more explanatory power than the initially calculated conditional logit models (adjusted R^2 = 0.08), although the overall direction of results was not altered (Table S5.7.1.). We modelled random parameter estimates of all the main attribute levels except the cost as normally distributed and all simulations were based on 1,000 Halton draws (Table 5.1.). WTP estimates for desirable attributes or WTA estimates for undesirable attributes were calculated using the parameter of the cost as the marginal utility of money. Standard errors of the WTP/WTA estimates were calculated using the Delta-method (Greene, 2000). It is not possible to directly compare the utility coefficients for different subsamples (e.g. experimental treatments, cities, socio-demographic variables) due to potential scale effects. Therefore, we compared WTP estimates themselves because the scale parameter cancelled out when WTP was calculated. All choice models were constructed using NLOGIT (version 4.0, 2007). Finally, descriptive statistics and figures were generated in R (2017) and Datagraph (2017) respectively.

5.4. Results

A total of 1,489 people were approached and resulted in an overall response rate of 40 % (n = 589). Eight questionnaires (1.8%) were removed as answers to the full set of choices were not recorded. A further 19 respondents (3.2%) were excluded from further analyses to correct for serial non-participation. Therefore, our final sample was 563 respondents (N), providing responses to 3,378 completed choice sets resulting in 13,512 observations. A median of 33 questionnaires were completed per site (range: 24-45; IQR: 9). Although our sample was self-selected greenspace visitors, the sample was representative of each city with regards to regards to gender (Leeds: $G_{(2,1)} = 2.24$, p = 0.134; Bristol: $G_{(2,1)} = 0.02$, p = 0.876; Edinburgh: $G_{(2,1)} = 1.80$, p = 0.180) and age ($G_{(2,5)} = 2.58$, p = 0.763; $G_{(2,5)} = 9.65$, p = 0.086; $G_{(2,5)} = 5.06$, p = 0.409). Respondents predominantly recorded their ethnicity as White (92.5 % in Leeds, 96.1% in Bristol and 90.8% in Edinburgh). Consequently, the sample was significantly under-representative of non-white ethnicities in Leeds ($G_{(2,1)}$ = 10.89, p < 0.001) and Bristol $G_{(2,1)} = 22.44$, p < 0.001, but representative in Edinburgh ($G_{(2,1)}$ = 0.26, p = 0.606) (Table S5.7.2.). Respondents covered a broad household income range, comprising of individuals below and above the lower and upper national deciles of income (< £5,199 to > £52,000 per annum before tax).

5.4.1. Are people willing to pay for the creation of urban meadows in public greenspaces and which characteristics of urban meadows do people have a preference for?

In a random parameter choice model of the final sample (N = 563), all variables had the expected sign and were significantly different from zero, except for an additional five plant species (Figure 5.3., Table S5.7.3.). All attributes describing meadow characteristics were estimated as random parameters and significant estimates of standard deviations were obtained ($p \leq 0.01$). This indicates that preferences for the characteristics have a distribution and are heterogeneous across the study sample. As expected, the cost variable estimate was significant and negative (-0.04±0.002, $p \leq 0.01$) demonstrating that people had a mean negative utility for an increase in taxes. The parameter for an additional five plant species was not significantly different from zero, which suggests that respondents might see this increase as insignificant and thus had no WTP for it. All other variables in the full model had a statistically significant effect on WTP/WTA (at $p \leq 0.05$). For an increase in the number of plant species by 10 species, respondents expressed a WTP (±S.E.) of £4.92±2.19. Respondents were willing to pay £9.94±2.56 for an increase to 75% native species from the current situation of 50%. However, respondents found a decrease to 25% native species more undesirable than they found the equivalent increase, expressing a WTA of -£16.34±3.36. Participants were willing to pay £23.35±3.38 for an increase to medium quality for pollinating insects and £27.08±3.07 for an increase to high quality. Respondents expressed a positive WTP for a change in appearance to white flowers of £12.71±3.21. They expressed an even higher WTP for white, yellow and blue flowers of £33.76±3.42 and white, yellow, blue, pink and red flowers of £31.21±2.76. We also found a significant WTP for options that involved no change to the current management situation of £10.33±3.21.

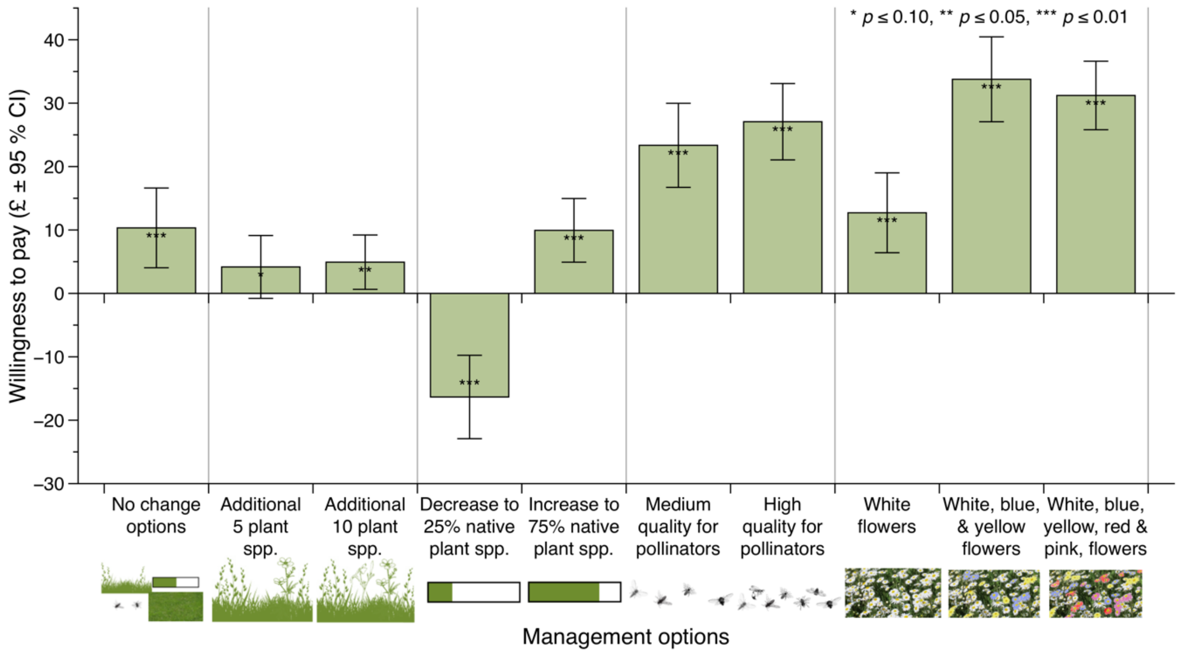


Figure 5.3. Peoples' willingness to pay (WTP) in GB£ per household per year, for changes in the management of amenity grass areas for the creation of wildflower meadows. From a random parameter model based on the full sample of 3378 observations from N = 563 respondents (χ^2 = 1899.91, pseudo-R^2 = 0.201, log-likelihood = -4682.90; Table S5.7.3.) Error bars display 95% confidence intervals.

5.4.2. How do these preferences change dependent on the characteristics of individuals or population/environmental factors?

We found no statistically significant differences between WTP estimates in the three experimental treatment types (Table S5.7.4.), between cities (Table S5.7.5.), or between genders (Table S5.7.6.).

When the sample was subset by individuals who had a higher or lower than median connectedness to nature (as measured by CNS), we found significant differences in individuals WTP for meadows characteristics (Figure 5.4., Table S5.7.7.). There was no significant difference between WTP for species richness and nativeness for these groups, for a medium increase in quality for pollinators. However, individuals with a higher CNS score had a significantly higher WTP for the creation of an urban meadow that was of high quality for pollinating insects (£43.46±6.00), than those with a lower CNS score (£18.63±3.42). Although we found no statistically significant difference between respondents split by CNS for the creation of urban meadows with white flowers, we found that individuals with a higher CNS score were more willing to pay for urban meadows with white, blue and yellow flowers (£55.18±7.77 versus £26.16±3.87). They were also more willing to pay for urban meadows with white, blue, yellow, red and pink flowers (£41.00±5.21 versus £21.65±3.13).

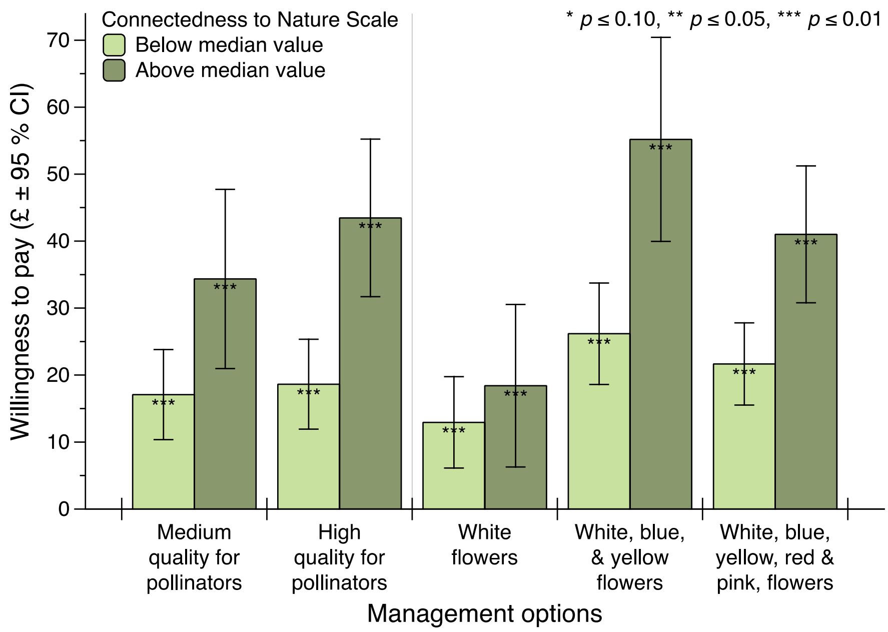


Figure 5.4. Peoples' willingness to pay (WTP) in £GB per household per year, for changes in the management of amenity grass areas for the creation of wildflower meadows. Split between individuals with below and above median connectedness to nature. The attributes of pollinator quality and appearance are displayed. From two random parameter models (Table S5.7.7.). Error bars display 95% confidence intervals.

5.5. Discussion

Given the role that urban areas can play in abating the ongoing pollinator crisis, and the imperative to create liveable and healthy cities, urban meadows have the potential to contribute to addressing environmental and social challenges. By means of a choice experiment, we provide evidence that urban greenspace users are willing to pay for the creation of urban meadows as an alternative to amenity grass. Although other studies have focused separately on the individual traits of urban meadows that people may prefer, ours is the first to employ a stated preference technique, requiring respondents to simultaneously consider trade-offs in their preferences for specific characteristics.

5.5.1. Preferences for species richness

On average, people were willing to pay to increase the species richness of sites by an additional 10 plant species, but not for an increase by five plant species. This supports previous work on urban meadow planting in the UK, which found people's preference for meadows increased with a higher plant species richness (Southon et al., 2017). However, we found WTP for increases in species richness were low, relative to the other attributes considered. Previous ecological economics studies have identified difficulties in attempting to capture people's value for actual biodiversity, arising from limitations in the extent to which the public understand ecological concepts (Christie et al., 2006; Bartkowski et al., 2015). Some biodiversity valuation studies have reported insufficient sensitivity of respondents' WTP for the scope of environmental change considered (Veisten et al., 2004). This may explain the relatively low value attributed to an increase by 10 plant species found in our study, as people did not consider this to be a large enough increase to be of benefit to them. Furthermore, a lower preference for plant richness could be related to the phenomenon of 'plant blindness', where it is reported that people lack the ability to see or notice plants and recognise their importance compared to other taxa (Allen, 2003).

5.5.2. Preferences for native species

We found a preference towards the creation of urban meadows with a higher proportion of native species, and a negative preference (of a greater magnitude) towards a decrease in the proportion of native species. Interestingly, the pattern of these preferences, where people tend to prefer avoiding losses to making equivalent gains, corresponds to the broader decision theory of loss aversion (Kahneman and Tversky, 1984), and indicates that people have an underlying utility for retaining existing native plant communities. Our findings diverge from those of Hoyle et al. (2017b), who found a majority of their study participants to be positive about non-native planting, and more so if told this vegetation was better adapted to a changing climate. However, that study was conducted in more vegetated public parks and botanical gardens, and considered a larger range of planting types. Therefore, the study participants may have therefore been more predisposed to preferring alternative planting types, having selected to visit such sites, when compared to visitors to urban greenspaces, such as those in our study. A bias towards support for native species was also found in a study of people's WTP for bird conservation in Denmark, which found people were willing to pay more for the conservation of birds that are currently native to Denmark, than for bird species emigrating into the country due to climate change (Lundhede et al., 2016). Preferences towards native species, and against non-native species, may be therefore driven by a combination of concerns about the potential of non-native to become invasive, and a form of patriotic value towards native species. Although we found people to theoretically state a preference against non-native meadows, people may be more accepting of such planting in practice. Indeed, people were unable to distinguish the difference between native and non-native planting during this study (Chapter 4), and it has been noted previously that people have a poor ability to identify non-native species (Robinson et al., 2016). People may have the expectation that non-native planting will look 'exotic', but this may not necessarily be the case (Lindemann-Matthies, 2016).

5.5.3. Preferences for quality for pollinators

Our respondents expressed a significant WTP towards urban meadows that increased the quality of areas for pollinating insects, although we found no difference between increases to 'medium quality' and 'high quality'. These results reveal that the public values urban meadows that provide refuge and forage for pollinators. This is similar to the findings of Southon et al. (2017), who found that if aware of their biodiversity benefits, people were more willing to tolerate meadows outside of the flowering season when they were less aesthetically pleasing. Hence, people appear to value the function that meadows can play in providing benefits to pollinators, if they understand this function. In economic terms, the values of an improved pollinator habitat could encompass a range of anthropocentric (e.g. that the respondent would benefit from aesthetic appreciation of increased floral displays nearby) or ecocentric values (e.g. based upon existence value, the notion pollinators have a right to exist) (Hargrove, 1989). However, it is not possible to easily disentangle the various values this attribute may encompass. Other stated preference studies have found that the public have a preference to avoid declines in pollinators and pollinator services (Mwebaze et al., 2010; Breeze et al., 2015). However, a key knowledge gap still exists regarding the extent publics know and understand the links between pollinators and pollination services, and how this may have changed over time (Hanley et al., 2015; Wilson et al., 2017). The levels of WTP we find for meadows that benefit pollinators, possibly stems from a greater awareness and concern about pollinator declines amongst members of the public. Further evidence for this can be seen via growth in the market for pollinator friendly garden plants, although whether such products reliably serve this intended function is questioned (Garbuzov and Ratnieks, 2014; Garbuzov et al., 2017).

While we found people to be supportive of improving the quality of an area for pollinators, people were not necessarily willing to pay for some of the specific ecological characteristics of urban meadows that may help to contribute to that goal, such as increased plant species richness, or non-native planting. Similarly, Garbuzov et al. (2015), in a study on reduced mowing, found that 97% of park visitors stated that they would support efforts to encourage pollinators and wildflowers. However, only 26% reported their enjoyment of the park increasing when this change was implemented. This indicates that although people may be theoretically supportive of enhancing urban greenspaces for pollinators, certain efforts to try to achieve that goal, such as reduced mowing, will not necessarily increase the majority of people's enjoyment of a site (or at least not consciously).

5.5.4. Preferences for appearance

Preferences towards meadows varied dependent on their appearance, and people attached a noticeably higher value to an increase in the colour of urban meadows. However, this relationship was not linear. This could be because people desire a balance between more visually impressive and subtler features of planting. For example, another study on urban meadows found that while colourful planting had the highest ratings in terms of aesthetic preferences, and was appreciated for its ‘wow factor’, subtler planting (e.g. greener, less flower cover) afforded a more restorative effect (Hoyle et al., 2017a). Beyond the simplified characteristics we investigated here, there are cultural norms involved in ecological design, such as the ‘neatness/messiness’ of planting (Nassauer et al., 2009). It may therefore be that certain forms of planting are regarded as more ‘fitting’ within the landscape. We recognise that our appearance attribute was limited to one-dimension, and only involved an increase in the number of visible colours in the same manipulated image. There are many other visual factors that may influence aesthetic appreciation, such as the structural diversity, the proportion of floral coverage, the relative abundance of different species, the overall shape and size of a meadow and less objectively measurable qualities such as ‘neatness’ or ‘wildness.

5.5.5. Heterogeneity in preferences between individuals

We did not find a significant difference in people’s WTP between the experimental treatments within the study (i.e. if the individual was next to a particular type of urban meadow intervention). Similarly, we did not find any significant differences in WTP for meadows between cities, or between genders. However, we did find marked differences in people’s WTP due to their emotional connection to the natural world, as measured by the psychometric connectedness to nature scale (CNS). Individuals who scored higher on CNS had a significantly higher WTP for meadows of a high quality for pollinating insects, and for more colourful urban meadows. Previous studies have found CNS to be predictive of pro-environmental behaviours (Mayer and Frantz, 2004; Mayer et al., 2009; Geng et al., 2015). Likewise, Southon et al. (2017) found that people characterised with a greater ‘eco-centricity’ (those who visited the countryside more, had a greater ability to identify plant species and exhibited more support for conservation) responded more positively to the creation of meadows. Hence, the extent of people’s emotional connectedness to the natural world may translate to real-world implications with regards to their support and acceptance of ecological interventions in greenspaces. Interestingly, colourful urban meadows may also produce additional co-benefits, difficult to fit into traditional specific categories of ecosystem services. In one of the greenspaces included in our study, the planting of urban meadows was reported to have discouraged antisocial behaviour due to changing the social atmosphere of the area, and therefore continued to be funded by the Police and Crime Commissioner’s Community Action fund (The Guardian, 2014; Mail Online, 2014).

5.5.6. Conclusions and implications

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services states an ambition with regards to pollinators and pollination services to ‘transform society’s relationship with nature’, suggesting that one way to do this is through the management of urban greenspaces for pollinators (IPBES, 2016). Our findings provide evidence that the public are likely to be supportive of efforts to create urban meadows for pollinator conservation in their nearby greenspaces, and that promoting pollinator communities in urban areas could form part of larger initiatives for biodiversity conservation in cities (Aronson et al., 2017; Nilon et al., 2017). Strong public concern for pollinators suggests that there is scope for enhancing participation in pollinator conservation. More broadly, when designing interventions such as urban meadows, it may be beneficial for greenspace managers to follow the design principle of 'form follows function', while focusing on communicating the benefits of interventions that provide public benefits. This approach is likely to result in win-wins for human well-being and biodiversity conservation.

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5.7. Supporting information

Appendix S5.7.1. Choice experiment analysis approach

To determine the relative importance of attributes within a choice experiment, complex probabilistic analysis is required. In our paper, we report the results of a random parameter logit model, an extension of most basic conditional logit. We provide a short description of the specification of both models below, in addition to the underpinning Random Utility Model.

Our model, as is common in the choice modelling literature, assumes the utility of a good can be described as a function of its attributes (Train, 2003). In a choice set where alternative versions of a good are described by variation in their attributes, respondents are assumed to choose the alternative good that gives them the highest indirect utility. Since it is not possible to perfectly observe an individual's utility, the Random Utility Model is used to form the basis for estimation. It is formally described as:

$$U_{ij} = V_{ij}\left(y_i - t_j, x_j, z_i\right) + \varepsilon_{ij}$$

Where U_{ij} represents individual i's indirect utility from a change in management of an area of amenity grass. The term V_{ij} is deterministic and is a function of individual i's income y subtracted by a tax payment t for alternative j, the alternative's attributes x_j and the individual's characteristics, z_i. The error term ε_{ij} is stochastic, meaning it cannot be observed by the analyst. If we assume the error elements to be identically and independently drawn from an extreme value distribution, the Random Utility Model is specified as 'conditional logit'.

If the utility function U is linear in its arguments and collecting all the arguments in the vector x_{ki} for a given specific alternative k among the J choice alternatives and individual i choosing, we can write $U_{ki} = \beta' x_{ki}$ where β is a vector of parameters describing alternatives in terms of: the number of plant species, proportion of native species, quality for pollinating insects, appearance and the price of the policy option. Using the conditional logit model, the probability of an individual i choosing alternative k over a set of alternatives J is given by:

$$Pr_i(k) = \frac{\mathrm{e}^{\mu\beta' x_{ki}}}{\sum_i^J \mathrm{e}^{\mu\beta' x_{ki}}}$$

Where μ is a scale parameter which for simplicity is typically normalised to utility.

In our analyses, we used one of a variety of extensions to this model which allows for describing and estimating a distribution for β as random parameters, and hence account for preference heterogeneity in the population. This overcomes a limitation in the conditional logit model, by allowing for random taste variation, unrestricted substitution patterns and correlation in unobserved factors over time (Train, 2003). This random parameter logit model (Train and Weeks, 2005) describes the probabilities as integrals of the standard conditional logit function over the distribution of βin the n'th choice occasion:

$$Pr_{in}(k) = \int \left(\frac{\mathrm{e}^{\mu \beta_i{}' x_{ki} n}}{\sum_i^J \mathrm{e}^{\mu \beta_i{}' x_{kin}}} \right) \varphi(\beta | b, W) d\beta$$

Here $\varphi(\beta|b,W)$ is the distribution function for β with a mean b and covariance W.

Estimation of the likelihood function based on the random parameter logit model requires that assumptions and specifications are made about which coefficients are random and the joint distribution of these coefficients. In our random parameter model we assumed all parameters except price are normally distributed. Significant standard deviations were obtained in all models for all parameters (p ≤ 0.01), except in specific cases where noted, indicating that preferences for the characteristics were heterogeneous across the study sample. It is worth nothing that this model implies an explicit estimation of the nature of the variation in preferences across individuals, in the form of a density function, but this is different from the unexplained variation in choices which is captured by the error term in the Random Utility Model above.

Appendix S5.7.2. Serial non-response protest statements

Respondents who chose the no choice option across all choice cards were asked the debriefing question below. Respondents who chose options 3, 7, 9 or 10 were considered to be protesting against the payment vehicle or the questionnaire itself and were removed from subsequent analysis (von Haefen et al., 2005; Mayerhoff et al., 2014).

If, in the preceding choice tables you always selected choice D (the current situation). Please indicate which, if any, of the statements listed below most closely match your reason for this choice. (***Choose one option***):

1. Grassy areas in parks do not mean anything to me
2. I would prefer parks to continue to be managed as they are now
3. I already pay enough taxes and the City Council should pay for this management change
4. The trade off between the different attributes made the “current situation” the best alternative in all choice sets
5. I do not think it is important to finance this management change
6. I prefer to spend my money on other things
7. I do not think the changes in management will have an effect
8. I could not relate to the background information
9. The initiatives should not be funded through taxation
10. The choices were difficult to relate to
11. It was too expensive as compared to what I would get out of these management changes
12. I could not afford any of the proposed initiatives
13. Other (please specify): ____________________

Only one ‘other’ statement was deemed to be protesting against the questionnaire: “Too confusing to respond to rationally”. The 23 remaining ‘other’ responses were deemed as genuine serial non-responses to the choice experiment and so were retained in the main sample dataset for analyses.

Table S5.7.1. Parameter estimates and Willingness To Pay (WTP) in GB£ per household per year of peoples' preferences towards the creation of flower meadows of varying characteristics. From a conditional logit model based on a full sample of 3378 observations from 563 respondents (pseudo-R^2 = 0.083, log-likelihood = -4093.88) .* p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

Variable		**Parameter**			**WTP**		
		Value		**Standard error (SE)**	**Value (in £)**		**SE**
No change options (ASC)		0.099	NS	0.096	3.917	NS	3.826
Number of plant species	An additional 5 plant species	0.028	NS	0.068	1.098	NS	2.690
	An additional 10 plant species	0.164	***	0.052	6.496	***	2.130
Proportion of native species	Decrease to 25%	-0.500	***	0.079	-19.821	***	3.572
	Increase to 75%	0.286	***	0.066	11.344	***	2.487
Quality for pollinating insects	Medium quality	0.623	***	0.076	24.683	***	3.421
	High quality	0.915	***	0.065	36.251	***	2.830
Appearance	White flowers	0.651	***	0.099	25.798	***	3.830
	White, yellow and blue flowers	1.105	***	0.085	43.773	***	4.003
	White, yellow, blue, pink and red flowers	0.874	***	0.070	34.620	***	2.457
Price		-0.025	***	0.001			

Table S5.7.2. Socio-demographic and economic characteristics of the final sample and comparison to population statistics (Eurostat, 2017). Two-tailed G-tests of goodness-of fit show where the sample deviates from the expected proportion based on the general population. *Note where sample is disaggregated figures may not sum to the total in each city due to respondents who chose to not disclose specific characteristics.

City		**Leeds**			**Bristol**			**Edinburgh**		
		Sample*	% sample	City % over 18	Sample*	% sample	City % over 18	Sample*	% sample	City over 18 %
Total (N)	563	216			152			195		
Gender	Male	95	43.98	49.07	75	49.34	48.71	88	45.13	49.93
	Female	121	56.02	50.93	77	50.66	51.29	107	54.87	50.07
G-test		$G_{(2,1)}$=2.24, p=0.134			$G_{(2,1)}$=0.02, p=0.876			$G_{(2,1)}$=1.80, p=0.180		
Age group	18 – 24	29	13.43	13.14	16	10.53	13.74	16	8.25	11.85
	25 – 34	42	19.44	19.71	35	23.03	24.21	39	20.10	22.82
	35 – 44	39	18.06	16.95	34	22.37	17.41	33	17.01	17.21
	45 – 54	43	19.91	16.82	25	16.45	15.31	37	19.07	16.46
	55 – 64	26	12.04	13.27	25	16.45	11.91	31	15.98	13.09
	65 and over	37	17.13	20.11	17	11.18	17.41	38	19.59	18.58
G-test		$G_{(2,5)}$=2.58, p=0.763			$G_{(2,5)}$=9.65, p=0.086			$G_{(2,5)}$=5.06, p=0.409		
Ethnicity	All white	197	92.49	85.10	146	96.05	83.97	177	90.77	91.80
	All non-white	16	7.51	14.90	6	3.95	16.03	17	9.23	8.20
G-test		$G_{(2,1)}$=10.89, p<0.001			$G_{(2,1)}$=22.44, p<0.001			$G_{(2,1)}$=0.26, p=0.606		
Income group	Up to £5,199	8	4.76		2	1.55		12	6.74	
	£5,200 - £10,399	9	5.36		7	5.43		18	10.11	
	£10,400 - £15,599	14	8.33		15	11.63		18	10.11	
	£16,000 - £20,779	16	9.52		9	6.98		28	15.73	
	£20,800 - £25,999	18	10.71		9	6.98		20	11.24	
	£26,000 - £31,199	22	13.10		25	19.38		20	11.24	
	£31,200 - £36,399	21	12.50		12	9.30		19	10.67	
	£36,400 - £51,999	30	17.86		19	14.73		24	13.48	
	£52,000 and above	30	17.86		31	24.03		19	10.67	

Table S5.7.3. Full model parameter estimates and Willingness To Pay (WTP) in £GB per household per year of peoples' preferences towards the creation of urban wildflower meadows. From a random parameter model based on the full sample of 3378 observations from N = 563 respondents (χ^2 = 1899.91, pseudo-R^2 = 0.201, log-likelihood = -4682.90). * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

Variable		Parameter			Standard deviation			WTP		
		Value		**Standard error (SE)**	**Value**		**SE**	**Value (in £)**		**SE**
No change options (ASC)		0.440	***	0.134				10.330	***	3.207
Number of plant species	An additional 5 plant species	0.178	NS	0.109	0.815	***	0.156	4.171	*	2.528
	An additional 10 plant species	0.210	**	0.093	0.948	***	0.116	4.923	**	2.187
Proportion of native species	Decrease to 25%	-0.695	***	0.134	1.494	***	0.159	-16.339	***	3.355
	Increase to 75%	0.423	***	0.114	1.309	***	0.125	9.942	***	2.561
Quality for pollinating insects	Medium quality	0.994	***	0.138	1.908	***	0.161	23.350	***	3.382
	High quality	1.152	***	0.138	1.988	***	0.132	27.075	***	3.072
Appearance	White flowers	0.541	***	0.139	0.617	***	0.193	12.714	***	3.214
	White, yellow and blue flowers	1.437	***	0.127	0.804	***	0.236	33.764	***	3.415
	White, yellow, blue, pink and red flowers	1.328	***	0.124	1.631	***	0.134	31.214	***	2.755
Price		-0.043	***	0.002						

Table S5.7.4. Parameter and Willingness To Pay (WTP) estimates in GB£ per household per year of peoples' preferences towards changes in the management of amenity grass areas for the creation of wildflower meadows. From three random parameter logit models split between groups of respondents who were beside different treatment types; (a) control meadows, (b) annual meadows (c) perennial meadows. * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

Variable		**Parameter**			**Standard deviation**			**WTP**		
		Value		**SE**	**Value**		**SE**	**Value (in £)**		**SE**
Model a – Respondents by a 'control meadow'. Based on 1170 observations from 195 respondents (χ^2 = 723.43, pseudo-R^2 = 0.219, log-likelihood = -1260.25)										
No change options (ASC)		0.280	NS	0.240				5.762	NS	4.950
Number of plant species	An additional 5 plant species	-0.036	NS	0.201	0.868	***	0.271	-0.749	NS	4.152
	An additional 10 plant species	0.011	NS	0.167	0.839	***	0.256	0.221	NS	3.430
Proportion of native species	Decrease to 25%	-1.033	***	0.271	1.834	***	0.300	-21.232	***	5.977
	Increase to 75%	0.683	***	0.214	1.508	***	0.227	14.036	***	4.189
Quality for pollinating insects	Medium quality	0.866	***	0.270	2.422	***	0.313	17.804	***	5.660
	High quality	0.990	***	0.265	2.414	***	0.276	20.345	***	5.250
Appearance	White flowers	0.454	*	0.255	0.957	***	0.362	9.329	*	5.196
	White, yellow and blue flowers	1.790	***	0.262	1.556	***	0.301	36.796	***	6.077
	White, yellow, blue, pink and red flowers	1.507	***	0.233	1.858	***	0.252	30.987	***	4.523
Price		-0.049	***	0.005						
Model b – Respondents by an 'annual meadow'. Based on 1074 observations from 179 respondents (χ^2 = 586.15, pseudo-R^2 = 0.192, log-likelihood = -1195.80)										
No change options (ASC)		0.924	***	0.241				27.890	***	7.880
Number of plant species	An additional 5 plant species	0.212	NS	0.170	0.442	NS	0.341	6.395	NS	5.012
	An additional 10 plant species	0.254	*	0.139	0.630	***	0.232	7.669	*	4.265
Proportion of native species	Decrease to 25%	-0.718	***	0.214	1.187	***	0.230	-21.648	***	7.125
	Increase to 75%	0.150	NS	0.187	1.352	***	0.205	4.528	NS	5.531
Quality for pollinating insects	Medium quality	0.734	***	0.205	1.393	***	0.258	22.138	***	6.586
	High quality	0.909	***	0.197	1.557	***	0.182	27.439	***	5.815
Appearance	White flowers	0.598	***	0.228	0.467	*	0.258	18.027	***	6.698
	White, yellow and blue flowers	1.403	***	0.207	0.538	NS	0.481	42.337	***	7.543
	White, yellow, blue, pink and red flowers	1.237	***	0.195	1.448	***	0.197	37.315	***	5.758
Price		-0.033	***	0.004						
Model c – Respondents by a 'perennial meadow'. Based on 1134 observations from 189 respondents (χ^2 = 671.02, pseudo-R^2 = 0.209, log-likelihood = -1236.55)										
No change options (ASC)		0.150	NS	0.227				3.364	NS	5.120
Number of plant species	An additional 5 plant species	0.255	NS	0.190	0.946	***	0.268	5.723	NS	4.201
	An additional 10 plant species	0.275	*	0.159	1.010	***	0.203	6.182	*	3.583
Proportion of native species	Decrease to 25%	-0.653	***	0.228	1.278	***	0.254	-14.673	***	5.407
	Increase to 75%	0.381	**	0.184	0.951	***	0.227	8.562	**	4.002
Quality for pollinating insects	Medium quality	1.395	***	0.239	1.871	***	0.254	31.349	***	5.745
	High quality	1.533	***	0.232	1.919	***	0.224	34.451	***	5.093
Appearance	White flowers	0.642	***	0.231	0.140	NS	1.259	14.417	***	5.075
	White, yellow and blue flowers	1.297	***	0.218	1.014	***	0.331	29.144	***	5.386
	White, yellow, blue, pink and red flowers	1.029	***	0.193	1.313	***	0.216	23.132	***	4.070
Price		-0.045	***	0.004						

Table S5.7.5. Parameter and Willingness To Pay (WTP) estimates in GB£ per household per year of peoples' preferences towards changes in the management of amenity grass areas for the creation of wildflower meadows. From three random parameter logit models split between groups of respondents in three cities; (a) Leeds (b) Bristol (c) Edinburgh. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Variable		**Parameter**			**Standard deviation**			**WTP**		
		Value		**SE**	**Value**		**SE**	**Value**		**SE**
Model a – Respondents in Leeds. Based on 1296 observations from 216 respondents (χ^2 = 722.50 pseudo-R^2 = 0.197, log-likelihood = -1435.39)										
No change options (ASC)		0.113	NA	0.208				2.425	NS	4.484
Number of plant species	An additional 5 plant species	0.387	**	0.168	0.578	*	0.330	8.328	**	3.545
	An additional 10 plant species	0.260	*	0.138	0.662	***	0.212	5.597	*	2.995
Proportion of native species	Decrease to 25%	-0.644	***	0.205	1.223	***	0.230	-13.854	***	4.675
	Increase to 75%	0.283	NS	0.180	1.262	***	0.203	6.093	NS	3.793
Quality for pollinating insects	Medium quality	1.067	***	0.213	1.841	***	0.251	22.956	***	4.884
	High quality	1.233	***	0.199	1.745	***	0.197	26.508	***	4.136
Appearance	White flowers	0.831	***	0.232	0.943	***	0.262	17.883	***	4.865
	White, yellow and blue flowers	1.634	***	0.213	1.048	***	0.251	35.139	***	5.157
	White, yellow, blue, pink and red flowers	1.440	***	0.198	1.550	***	0.201	30.979	***	3.958
Price		-0.046	***	0.004						
Model b – Respondents in Bristol. Based on 912 observations from 152 respondents (χ^2 = 516.18, pseudo-R^2 = 0.216, log-likelihood = -983.71)										
No change options (ASC)		0.548	**	0.265				11.093	**	5.445
Number of plant species	An additional 5 plant species	0.100	NS	0.215	0.293	NS	0.511	2.023	NS	4.330
	An additional 10 plant species	0.078	NS	0.200	1.085	***	0.251	1.575	NS	4.061
Proportion of native species	Decrease to 25%	-1.127	***	0.297	1.662	***	0.331	-22.838	***	6.514
	Increase to 75%	-0.017	NS	0.244	1.736	***	0.281	-0.349	NS	4.957
Quality for pollinating insects	Medium quality	0.884	***	0.297	2.373	***	0.330	17.900	***	6.202
	High quality	0.892	***	0.290	2.293	***	0.306	18.067	***	5.677
Appearance	White flowers	0.557	**	0.281	0.885	**	0.348	11.281	**	5.601
	White, yellow and blue flowers	1.646	***	0.288	1.306	***	0.381	33.338	***	6.465
	White, yellow, blue, pink and red flowers	1.444	***	0.286	2.072	***	0.303	29.243	***	5.428
Price		-0.049	***	0.005						

Model c – Respondents in Edinburgh. Based on 1170 observations from 195 respondents (χ^2 = 698.64 pseudo-R^2 = 0.211, log-likelihood = -1272.64)										
No change options (ASC)		0.593	**	0.238				17.497	**	7.348
Number of plant species	An additional 5 plant species	0.007	NS	0.195	1.135	***	0.246	0.193	NS	5.749
	An additional 10 plant species	0.181	NS	0.158	1.083	***	0.210	5.332	NS	4.652
Proportion of native species	Decrease to 25%	-0.895	***	0.228	0.950	***	0.283	-26.398	***	7.499
	Increase to 75%	0.712	***	0.190	1.267	***	0.212	21.009	***	5.272
Quality for pollinating insects	Medium quality	0.930	***	0.223	1.529	***	0.260	27.430	***	7.119
	High quality	1.304	***	0.238	2.333	***	0.258	38.461	***	6.986
Appearance	White flowers	0.570	**	0.250	0.849	***	0.237	16.813	**	7.189
	White, yellow and blue flowers	1.632	***	0.252	1.485	***	0.259	48.145	***	8.766
	White, yellow, blue, pink and red flowers	1.218	***	0.204	1.528	***	0.231	35.933	***	5.776
Price		-0.034	***	0.004						

Table S5.7.6. Parameter and Willingness To Pay (WTP) estimates in GB£ per household per year of peoples' preferences towards changes in the management of amenity grass areas for the creation of wildflower meadows. From two random parameter logit models split by gender; (a) men (b) women. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$

Variable		**Parameter**			**Standard deviation**			**WTP**		
		Value		**Standard error (SE)**	**Value**		**SE**	**Value (in £)**		**SE**
Model a – Male respondents. Based on 1548 observations from 258 respondents ($\chi^2 = 803.28$, pseudo-$R^2 = 0.183$, log-likelihood = -1744.34).										
No change options (ASC)		0.381	**	0.192				10.367	**	5.281
Number of plant species	An additional 5 plant species	0.010	NS	0.153	0.646	***	0.228	0.280	NS	4.160
	An additional 10 plant species	0.126	NS	0.123	0.587	**	0.234	3.437	NS	3.361
Proportion of native species	Decrease to 25%	-0.840	***	0.190	1.279	***	0.245	-22.854	***	5.703
	Increase to 75%	0.365	**	0.166	1.357	***	0.184	9.939	**	4.393
Quality for pollinating insects	Medium quality	0.800	***	0.200	2.058	***	0.237	21.762	***	5.694
	High quality	0.926	***	0.188	1.941	***	0.183	25.213	***	4.983
Appearance	White flowers	0.383	**	0.194	0.630	**	0.265	10.412	**	5.173
	White, yellow and blue flowers	1.411	***	0.186	0.934	***	0.249	38.398	***	5.896
	White, yellow, blue, pink and red flowers	0.936	***	0.175	1.626	***	0.188	25.475	***	4.538
Price		-0.037	***	0.003						
Model b – Female respondents. Based on 1830 observations from 305 respondents ($\chi^2 = 1134.61$, pseudo-$R^2 = 0.221$, log-likelihood = -1969.61).										
No change options (ASC)		0.426	**	0.186				9.277	**	4.129
Number of plant species	An additional 5 plant species	0.234	NS	0.150	0.815	***	0.254	5.085	NS	3.209
	An additional 10 plant species	0.202	NS	0.130	1.093	***	0.169	4.392	NS	2.833
Proportion of native species	Decrease to 25%	-0.737	***	0.185	1.282	***	0.222	-16.041	***	4.286
	Increase to 75%	0.404	***	0.151	1.123	***	0.176	8.794	***	3.157
Quality for pollinating insects	Medium quality	1.137	***	0.184	1.670	***	0.196	24.737	***	4.221
	High quality	1.377	***	0.188	1.959	***	0.184	29.947	***	3.883
Appearance	White flowers	0.782	***	0.193	0.662	*	0.367	17.010	***	4.115
	White, yellow and blue flowers	1.589	***	0.192	1.434	***	0.249	34.564	***	4.646
	White, yellow, blue, pink and red flowers	1.554	***	0.169	1.512	***	0.173	33.804	***	3.424

Price	-0.046	***	0.003

Table S5.7.7. Parameter and Willingness To Pay (WTP) estimates in in GB£ per household per year of peoples' preferences towards changes in the management of amenity grass areas for the creation of wildflower meadows. From two random parameter logit models split between respondents who were (a) lower than the median Connectedness to Nature (CNS) score and (b) higher than the median CNS. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Variable		**Parameter**			**Standard deviation**			**WTP**		
		Value		**Standard error (SE)**	**Value**		**SE**	**Value (in £)**		**SE**
Model a – Respondents with a below median CNS score. Based on 1596 observations from 266 respondents (χ^2 = 986.68, pseudo-R^2 = 0.220, log-likelihood = -1719.18).										
ASC		0.200	NS	0.189				3.289	NS	3.108
Number of plant species	An additional 5 plant species	0.335	**	0.167	0.768	***	0.239	5.505	**	2.696
	An additional 10 plant species	0.209	NS	0.133	0.307	NS	0.347	3.430	NS	2.192
Proportion of native species	Decrease to 25%	-0.778	***	0.210	1.401	***	0.222	-12.771	***	3.623
	Increase to 75%	0.377	**	0.171	1.298	***	0.206	6.178	**	2.722
Quality for pollinating insects	Medium quality	1.041	***	0.206	1.950	***	0.233	17.077	***	3.432
	High quality	1.135	***	0.221	2.367	***	0.238	18.631	***	3.421
Appearance	White flowers	0.788	***	0.219	1.188	***	0.239	12.931	***	3.479
	White, yellow and blue flowers	1.595	***	0.221	1.703	***	0.245	26.167	***	3.866
	White, yellow, blue, pink and red flowers	1.320	***	0.203	2.035	***	0.226	21.655	***	3.131
Price		-0.061	***	0.004						
Model b – Respondents with an above median CNS score. Based on 1782 observations from 297 respondents (χ^2 = 1016.74, pseudo-R^2 = 0.203, log-likelihood = -1962.01).										
ASC		0.526	***	0.191				17.581	***	6.624
Number of plant species	An additional 5 plant species	-0.039	NS	0.147	0.846	***	0.241	-1.310	NS	4.938
	An additional 10 plant species	0.160	NS	0.126	1.131	***	0.148	5.367	NS	4.235
Proportion of native species	Decrease to 25%	-0.889	***	0.170	1.022	***	0.238	-29.724	***	6.649
	Increase to 75%	0.317	**	0.151	1.299	***	0.176	10.600	**	4.887
Quality for pollinating insects	Medium quality	1.027	***	0.183	1.724	***	0.198	34.347	***	6.827
	High quality	1.300	***	0.173	1.800	***	0.166	43.460	***	6.004
Appearance	White flowers	0.550	***	0.188	0.669	***	0.244	18.407	***	6.192
	White, yellow and blue flowers	1.650	***	0.183	1.119	***	0.194	55.180	***	7.770
	White, yellow, blue, pink and red flowers	1.226	***	0.155	1.293	***	0.173	41.001	***	5.211
Price		-0.030	***	0.003						

Appendix S5.7.3. Supporting information references

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Chapter 6. Associations between neighbourhood greenspace accessibility, naturalness and population level physical activity in Kent, UK

Due for submission to *PLoS ONE*.

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6.1. Abstract

Physical activity promotes good physical and mental health across the life span, and one way in which greenspaces are thought to lead to benefits for human health and well-being is through increases in physical activity levels in their surrounding populations. Policy makers are therefore interested in the potential of greenspaces to reduce the individual and societal costs of ill health. Yet knowledge gaps remain in the extent to which accessibility and variations in the quality of natural areas are important for the promotion of physical activity. Our study examined associations between access to greenspace, measured by the Accessible Natural Greenspace Standards (ANGSt), and physical activity levels amongst small populations in Kent, UK, while controlling for age and deprivation. Greenspaces were categorised according to naturalness levels recommended in the authority guidance. We found inconsistent evidence of the benefit of greenspace for physical activity. Levels of activity in the population were associated with a subset of the most small, close, greenspaces within urban areas, but a significant association was not found for most types of greenspace. This suggests that the influence of greenspace availability on physical activity levels may be variable between contexts and environmental quality. Experimental and longitudinal studies are needed to establish causality and to further investigate underlying mechanisms. The relevance, and application of greenspace accessibility standards is further discussed.

6.2. Introduction

Preventable noncommunicable diseases (NCDs), such as type 2 diabetes, certain cancers, cardiovascular diseases and mental illness are major factors affecting health and well-being globally (WHO, 2012). Beyond their impacts on an individual's health and well-being, the prevalence of NCDs has wider social costs, impacting upon public health care budgets and reducing the productivity of the workforce. For example, premature deaths from NCDs in 2013 represented an economic loss of €115 billion to the European Union (OECD, 2016). Many NCDs are linked to chronic stress and lifestyle factors such as an unhealthy diet and insufficient physical activity (Shortt et al., 2014). Globally, 31% of adults are classed as physically inactive (Hallal et al., 2012), and inactivity has been identified as the fourth leading risk factor for global mortality, accounting for 6% of deaths globally (WHO, 2009). Inactivity is more common in high income countries (WHO, 2012). In the UK, lack of physical activity directly contributes to one in six deaths, approximately the same proportion as caused by smoking tobacco (PHE, 2014). Social, cultural and economic trends have removed physical activity from the daily life of many people (Shortt et al., 2014), as fewer people have manual jobs and technology dominates at work and at home.

Interventions targeted at individuals have had limited success in increasing physical activity (Foster et al., 2005), partly because, only 20-40% of the reported variance in physical activity can be explained by individual depositions (Spence and Lee, 2003). Therefore, public health institutions and researchers are interested in the broader social and environmental factors that can influence and increase levels of physical activity in populations. Greenspaces, especially in urban areas, have the potential to help reduce physical inactivity in a population-wide, preventative way, as an 'upstream' intervention. These are considered more efficient than dealing with the consequences of ill health (Maller et al., 2006). Greenspaces have been linked to both the avoidance of ill health (pathogenesis) while also supporting good health and well-being (salutogenesis). It has also been suggested that access to greenspaces is also 'equigenic', reducing the inequalities in health outcomes normally associated with socio-economic inequalities (Mitchell et al., 2014). In addition to increasing physical activity (both frequency and intensity) access to greenspaces also leads to health benefits through improved air quality, stress reduction, attention restoration, greater social cohesion/contact/capital and immunological function (Hartig et al., 2014; WHO, 2016). Several studies have demonstrated an association between access to, and use of, greenspaces with increased physical activity and reduced sedentary time (Kaczynski and Henderson, 2007; 2008; Schipperijn et al., 2013; Lachowycz and Jones, 2014). Yet, it is not simply the presence, size or quantity of greenspaces that is associated with increased physical activity. Intriguingly, recent evidence suggests that some specific natural characteristics in greenspaces may further promote, and enhance the benefits of physical activity (Shanahan et al., 2016).

The link between greenspaces and physical activity and other predictors of health have been recognised at multiple governmental levels via various targets and policies. The United Nations Sustainable Development Goals includes the target to "by 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities" (UN, 2016) and in light of this the European Union has recognised the need to prioritise physical activity in an urban planning context (WHO, 2017). In the UK, the Natural Capital Committee recently recommended that specific targets should be set in the 25-year environment plan to ensure that everyone has access to local greenspace for recreation and the physical and mental health benefits it provides (DEFRA, 2017). However, little work has considered if and how, when implemented, these policies deliver their intended outcomes.

Our study set out to examine the association between access to greenspace and physical activity at a small population level, and the extent to which people met the government's recommended accessibility metrics. Locally identifying greenspace access within small geographic areas is a powerful tool for local planning, providing public health policy makers the relevant and specific information needed to make evidence-informed decisions and design effective interventions. We also considered if variations in the 'naturalness' of spaces, categorised according to the same guidance, impacts on activity levels. Therefore, our research questions were: (i) What proportion of the study population meet the current UK guidelines for physical activity? and; (ii) Does access to greenspace predict physical inactivity (while controlling for age and deprivation)?; and, (iii) How do (i) and (ii) vary spatially in urban and rural areas, and when considering variations in 'naturalness' of greenspaces?

6.3. Methodology

6.3.1. Study system

Recent public health indicators report that 28.4% of adults in the county of Kent, UK, are classified as inactive (national average = 27.7%) and 56.6% achieve at least 150 minutes of physical activity per week (national average = 57%). However, the same figures estimate that only 12.1% of the population in the county use outdoor space for exercise and health reasons, a figure below the national average of 17.1% (PHOF, 2014). Kent has some of the most affluent and most deprived communities in England, and these translate to inequalities in health outcomes (KPHO, 2016). Therefore, we used Kent as a case study to investigate the associations between greenspace and physical activity, while also acting as a practical assessment to be used for targeted local planning. For administrative purposes, the study was undertaken on the population within the Kent County Council area, therefore excluding the Medway Unitary Authority area.

We used Lower-layer Super Output Areas (LSOAs) as our smallest geographic unit of study (ONS, 2011a), to be amenable to the analysis of available physical activity and socio-demographic datasets. All spatial data were processed using ArcGIS (version 10.3.1; ESRI, 2011). Our study area of Kent has 902 LSOAs, each of which comprises a minimum of 1000 residents with a mean of 1,600. The geographic size of LSOAs are therefore dependent on population density. As previous research has found the effect of associations between health prevalence and greenspace to be modified by urban/rural status (Wheeler et al., 2015), the standard government rural-urban classification for output areas in England was used to categorise each LSOA according to population density and settlement dispersal (ONS, 2011b). This classifies urban areas as physical settlements with a population of 10,000 or more (Figure 6.1.).

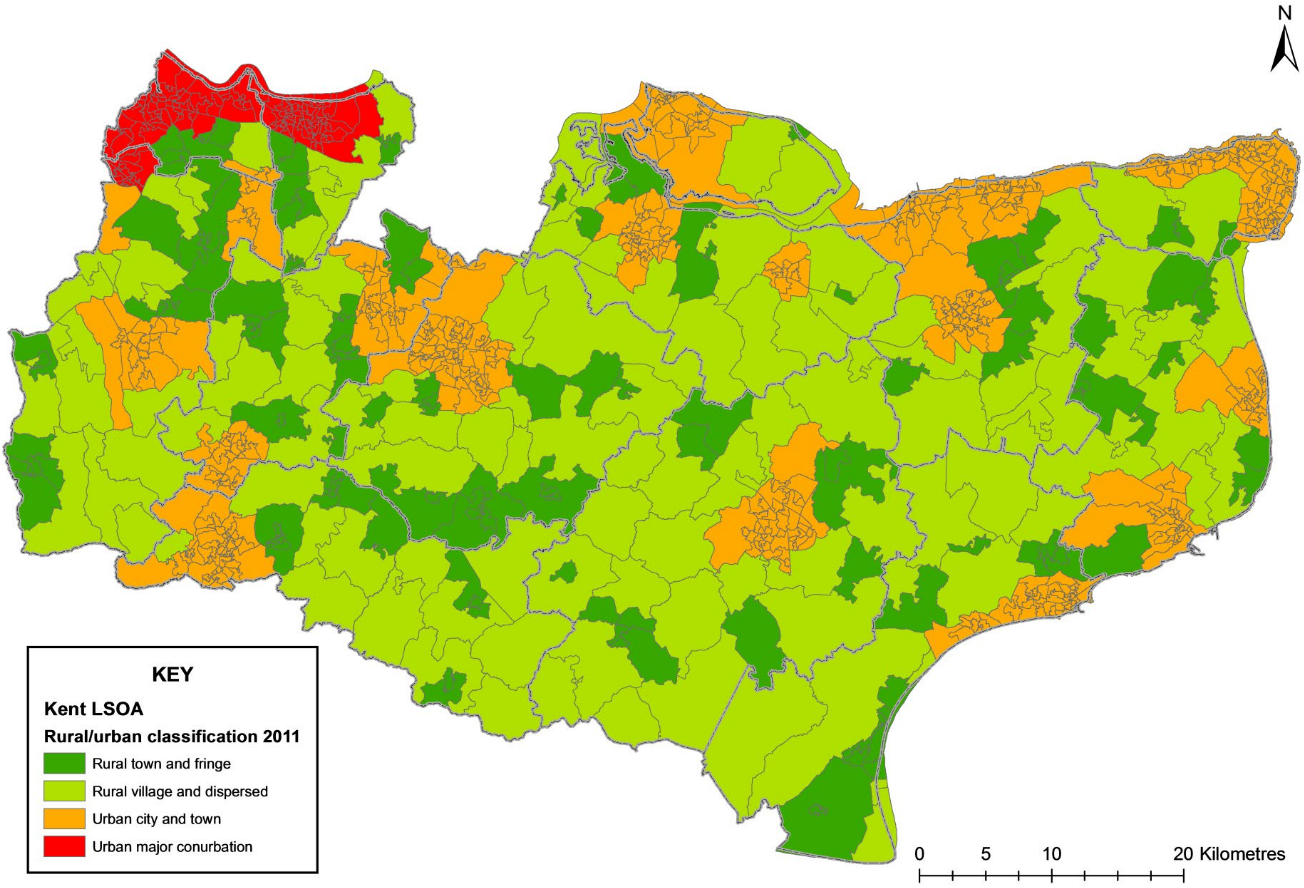

Figure 6.1. Rural-urban classification (ONS, 2011b) by Lower Super Output Areas (LSOAs) in Kent.

6.3.2. Greenspace and access route data

In the context of local planning greenspace is defined as 'all open space of public value, including not just land, but also areas of water such as rivers, canals, lakes and reservoirs which offer important opportunities for sport and recreation and can also act as a visual amenity' (ODPM, 2002). In this study, greenspace layers included open spaces categorised by the district local authorities according to the Planning Policy Guidance 17 (PPG17) typologies (ODPM, 2002) (Table 6.1.; Figure 6.2.). County-wide datasets of greenspace e.g. Local Nature Reserves, Wildlife Trust reserves, Woodland Trust reserves, state owned woodlands, village greens and common land were collated (for a full list of datasets used in the analysis see Table S6.7.1.). Any sites closed to the public were excluded, including school playing fields and farmland. In accordance with guidance issued by Natural England (the public body responsible for ensuring the protection of England's natural environment), greenspace was allocated to proxy levels of ‘feelings of naturalness’ associated with a particular site type (Table 6.2.) (Natural England, 2010). Open space types (PPG17) were allocated to corresponding naturalness levels (Table 6.3.). Where a greenspace coincided spatially with a woodland or nature reserve, the naturalness score was allocated to the higher naturalness level, in accordance with guidance (Natural England, 2010). For example, a churchyard categorised by the local authority may be attributed to naturalness level 3, however, if regional data (Kent Habitat Survey, 2012) indicated there to be woodland at the site, it would be reallocated as naturalness level 1. As access to sites could not be guaranteed, improved farmland was not considered in this study and therefore level 4 sites were excluded from the analysis.

Table 6.1. Typology under which greenspace GIS layers were categorised, as provided in the UK Planning Policy Guidance 17 (PPG17) (ODPM, 2002)

i.	Parks and gardens – including urban parks, country parks and formal gardens.
ii.	Natural and semi-natural urban greenspace – including woodlands, urban forestry, scrub, grasslands (e.g. downlands, commons, meadows) wetlands, open and running water, wastelands and derelict open land and rock areas (e.g. cliffs, quarries, pits).
iii.	Green corridors – including river and canal banks, cycleways, and rights of way.
iv.	Outdoor sports facilities (with natural or artificial surfaces and either publicly or privately owned) – including tennis courts, bowling greens, sports pitches, golf courses, athletics tracks, school and other institutional playing fields, and other outdoor sports areas.
v.	Amenity greenspace (most commonly, but not exclusively in housing areas) – including informal recreation spaces, greenspace in/around housing, domestic gardens and village greens.
vi.	Provision for children and teenagers – including play areas, skateboard parks, outdoor basketball hoops, and other more informal areas (e.g. ‘hanging out’ areas, teenage shelters).
vii.	Allotments, community gardens, and city (urban) farms.
viii.	Cemeteries and churchyards.
ix.	Accessible countryside in urban fringe areas.
x.	Civic spaces, including civic and market squares, and other hard surfaces areas designed for pedestrians.

Table 6.2. Site categorisation according to ‘feeling of naturalness’ (in accordance with Natural England, 2010).

Level 1
Nature conservation areas, including Sites of Special Scientific Interest (SSSIs)
Local sites, including local wildlife sites, Regionally Important Geological Sites (RIGS)
Local Nature Reserves (LNRs)
National Nature Reserves (NNRs)
Woodland
Remnant countryside (within urban and urban fringe areas)
Level 2
Formal and informal open space
Unimproved farmland
Rivers and canals
Unimproved grassland
Disused/derelict land, mosaics of formal and informal areas of scrub etc
Country parks
Open access land
Level 3
Allotments
Church yards and cemeteries
Formal recreation space
Level 4
Improved farmland

Table 6.3. Categorisation of greenspaces to naturalness levels (Table 6.2.) in accordance Planning Policy Guidance 17 (PPG17) open space categorisation types (Table 6.1).

PPG17 Type	Categorisation within naturalness level	Naturalness Level
Natural and semi-natural greenspace	Designated sites and woodland	1
	Other access land	2
Green corridors	Designated sites and woodland	1
	Other access land	2
Parks and gardens	Formal and Informal Open Space	2
	Country Parks	2
Outdoors sports facilities	Formal Recreation Space	3
Amenity greenspace	Formal Recreation Space	3
Provision for children and young people	Formal Recreation Space	3
Allotments	Allotments	3
Cemeteries	Cemeteries	3

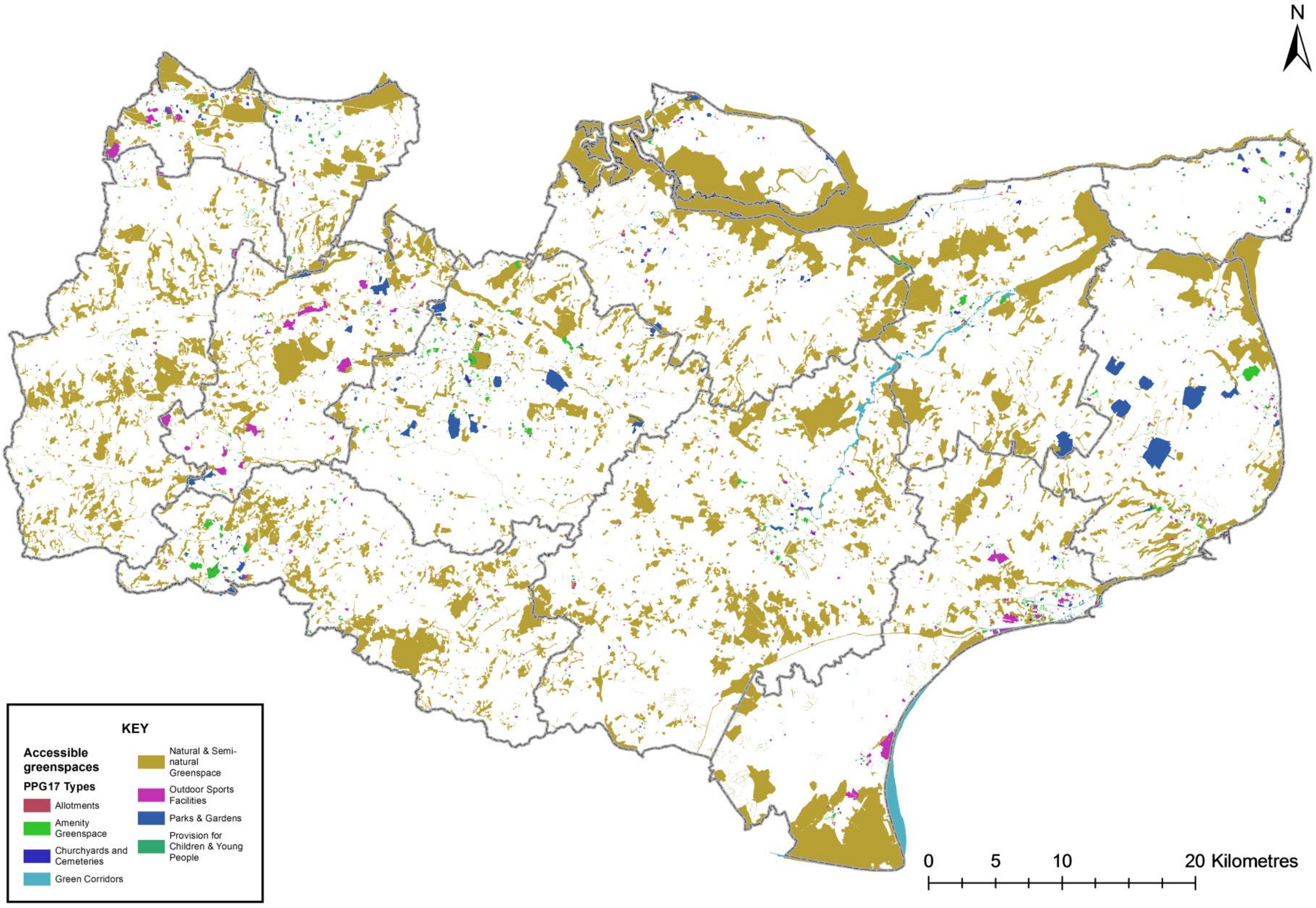

Figure 6.2. Greenspace in Kent allocated according to open space types (Planning Policy Guidance 17; ODPM, 2002)

To quantify the accessibility of greenspaces to the public, spatial datasets of the Public Rights of Way, Promoted Routes, Sustrans Routes and roadside footways were collated (supplied by the county council) (see Table S6.7.1.). To best represent how people are able to travel by foot, urban footways were extracted from the road layer. Pavements that did not cross roads or junctions in the data layer resulted in short non-contiguous fragments, and so we joined gaps of less than 30 m between end points and nearby routes. Where footways were present on both sides of a road within 10 m of each other, these were made into a single line. These distances were chosen based on sampling typical gap sizes via the Ordnance Survey base map. Government guidance recommend a minimum area of 0.25 ha when mapping accessible greenspace to identify opportunities to reduce greenspace provision deficiencies (Natural England, 2008). We therefore removed areas with an extent of less than 0.25 ha from each of the final combined naturalness layers. Once gaps between site fragments had been removed, the boundaries between adjacent polygons were dissolved to remove overlaps and create contiguous greenspace sites.

6.3.3. Socio-demographic and physical activity datasets

A point data layer of postcodes in Kent was extracted by using the grid reference for the building closest to the geographic centre in each postcode (ONS, 2016). Postcode level 2011 census population data was then attributed to the points to provide the total number of people and occupied households in each postcode. On average, there were 15.9 occupied households and 38.5 people per residential postcode in Kent. Any postcodes that did not include residential households were removed, so our analysis only considered greenspace access from where people live. Postcodes do not always align within LSOA boundaries, so each postcode was attributed to the LSOA in which our points were located, potentially introducing a small amount of error, where some households within a postcode area may have been located in an adjacent LSOA. Due to the established relationship between area deprivation and poorer health outcomes and behaviours, including physical activity (Sawyer et al., 2017), we extracted the Index of Multiple Deprivation (IMD) (Department for Communities and Local Government, 2015) for the LSOAs in Kent (Figure 6.3.).

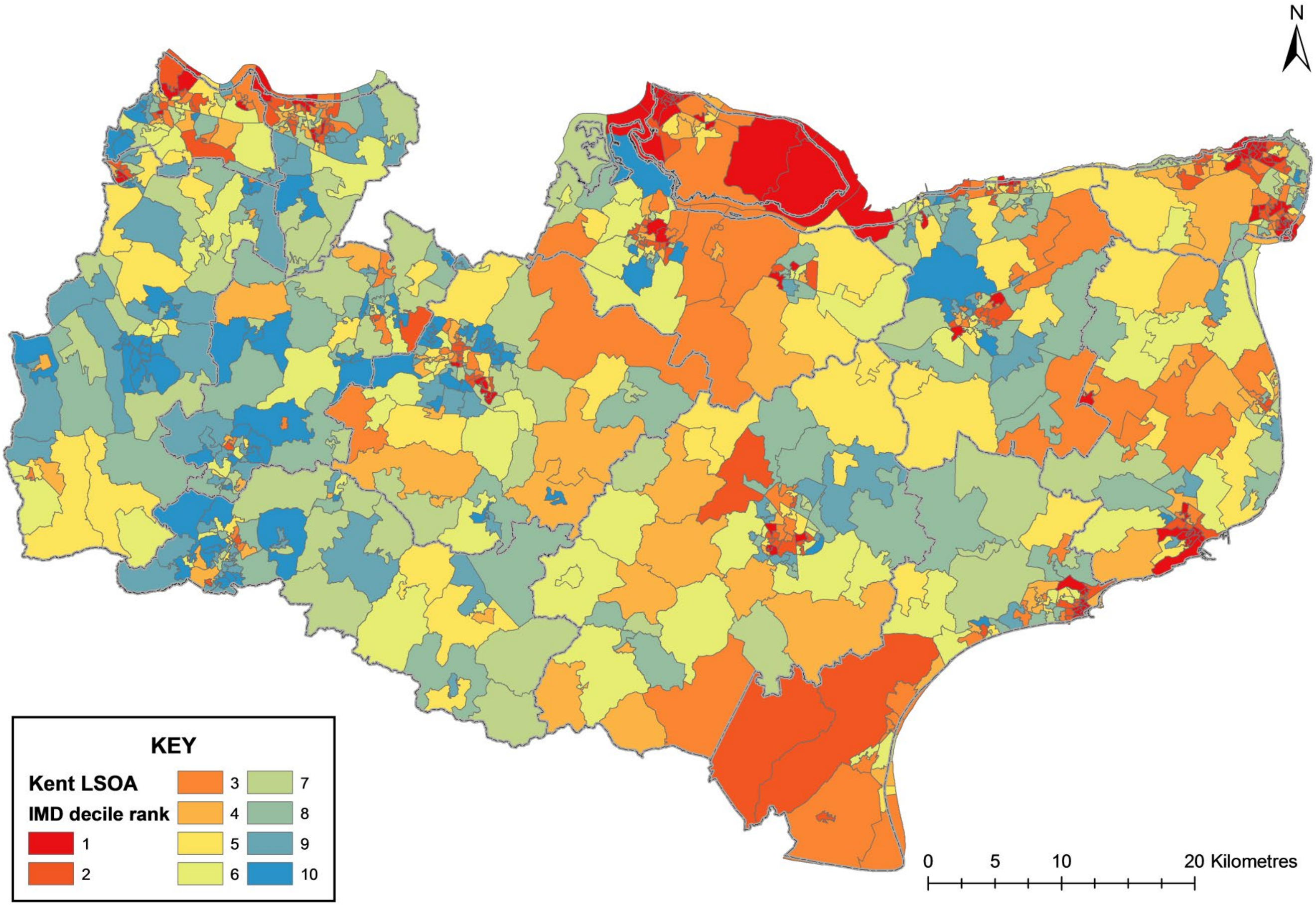

Figure 6.3. Deciles of socio-economic deprivation according to the Index of Multiple Deprivation (IMD) (Department for Communities and Local Government, 2015) for Lower Super Output Areas (LSOAs) in Kent.

We used a measure of population physical activity reported in Experian Mosaic segments (Experian, 2015), a commercial population profiling tool that assigns activity levels to subsections of the population and reports the data at an Output Area spatial resolution. The underpinning information comes from a Target Group Index Survey, which includes the following question on physical activity: “How many hours per week do you take part in sport or other types of exercise, such as walking, jogging or going to the gym?”. It should be noted that a limitation of these data is that the question does not breakdown exercise by location, however this limitation is balanced against the difficulty inherent in finding amenable small area population data that can be combined at an appropriate scale. The physically active proportion of the population might, therefore, be using indoor facilities to exercise, rather than greenspace or exercising in their garden or street. Nationally, data relating to almost 50 million people across the UK are used to build the Experian Mosaic segments, the projected proportion of people likely to be inactive is then projected in each area (see Appendix Table S6.7.2. for the relevant Experian Mosaic segments). Physically inactive people, reported in Experian Mosaic segments, are people who do not meet the Chief Medical Officer’s definition of physical activity (i.e. achieving at least 150 minutes of moderate intensity activity per week; Department of Health, 2011). Physical activity data in Experian Mosaic segments from 2013 were joined to the LSOA boundary layer, allowing the percentage of the population considered to be inactive to be estimated across the county by LSOA (Figure 6.4). The Experian Mosaic data indicated that 24% of the population of Kent could be considered physically inactive, which is comparable to the benchmark reporting from the Public Health Outcomes Framework statistic of 28%, with differences accounted by differences in methodology (PHOF, 2014). As the Experian Mosaic data is estimated based on factors such as deprivation, there was a moderate correlation between deprivation (IMD) and physical activity in LSOAs ($r_{900} = 0.39$, $p < 0.001$).

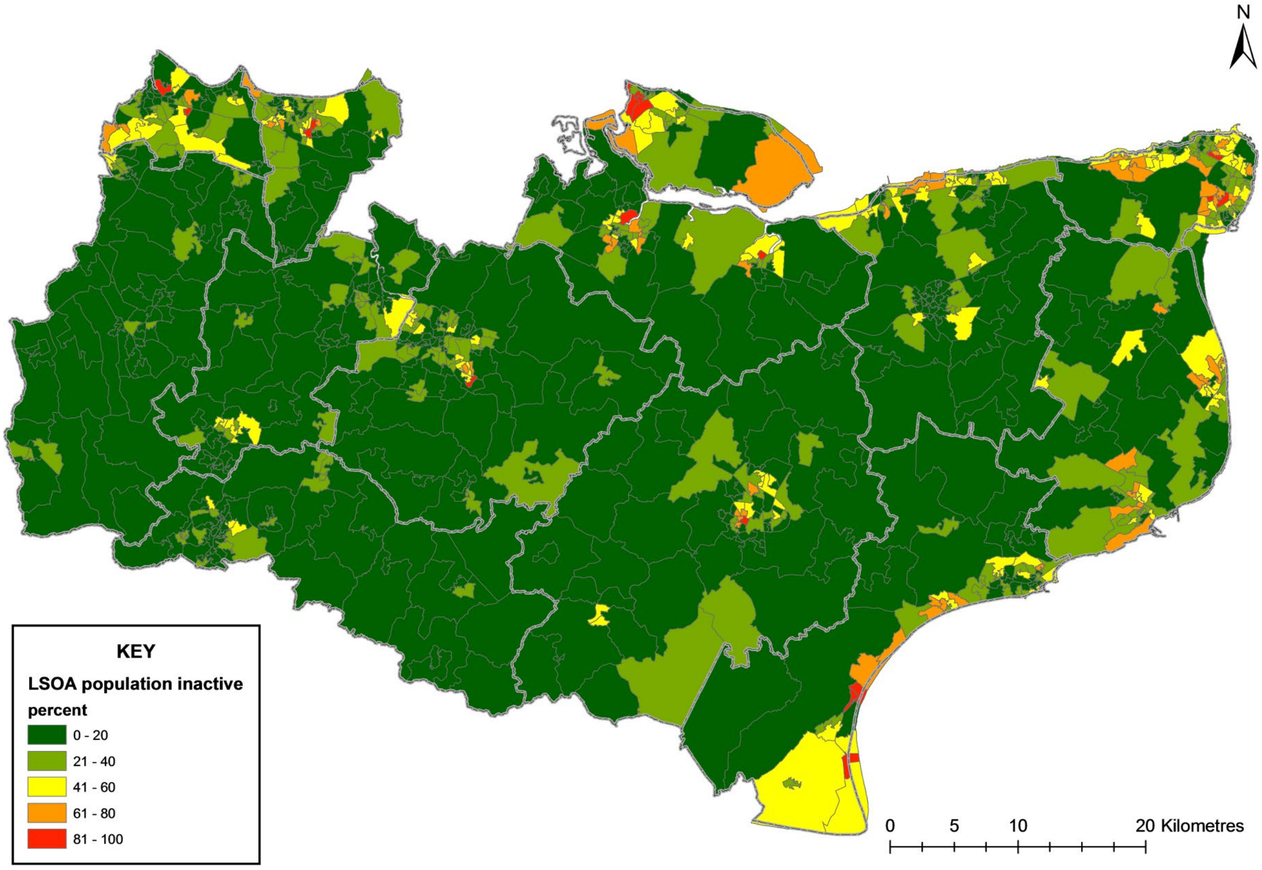

Figure 6.4. The proportion of the population considered physically inactive per Lower Super Output Area (LSOA) in Kent.

6.3.4. Establishing population greenspace proximity and access

Accessibility to greenspaces was assessed according to the Accessible Natural Greenspace Standards (ANGSt) (Natural England, 2010). The ANGSt recommends that people have access to sites at four proximity/area criteria: (i) at least 1 site >2 ha within 300 m of where people live; (ii) at least 1 site >20 ha within 2 km of where people live; (iii) at least 1 site >100 ha within 5 km of where people live; and (iv) at least 1 site >500 ha within 10 km of where people live. Accessibility to greenspaces is typically measured using the Euclidean distance (i.e. the 'as the crow flies' distance) from a household to the greenspace. However, to truly test if people are able to access greenspaces, we conducted our analysis using the pathways network, to more accurately model likely human behaviour. The distance to travel to greenspaces was calculated as the distance to travel along the pathway and pavement network from a postcode area to a greenspace entry point. As our dataset did not include entry points to greenspaces, an entry point was assumed to be any location where the access route layer intersected with the greenspace boundary (allowing for 10 m error, as above). Where two or more greenspace entry points fell within 20 m of each other, a single consolidated entry point was generated at the geometric centre to reduce the computational complexity of the analyses. Where there was a break in the access route, the GIS model assumed that travel via that route was not possible, even if the maximum travel distance has not been reached. The outputs from this were lines representing the access routes that could be travelled, from a greenspace entry point to the maximum distance for the accessibility standard being tested, and a polygon representing the area of influence of that line. The area of influence of the line was limited to a maximum of 100 m to either side of the line. The postcodes that fell within the area of influence were considered to have met the standard. In densely populated areas, where access routes were closely packed, the model automatically avoided falsely including areas associated with access routes beyond the maximum travelling distance; this meant that only those postcodes whose centroids were very close to the route were included. As it was not possible to first-hand assess whether each individual greenspace was truly accessible to the public within our GIS analysis, sites which were more than 10 m from an access route were excluded. This tolerance was chosen because it accounts for any error associated with the creation of the access route layer.

6.3.5. Statistical analyses

We used the natural logarithm of the IMD score in all analyses, as this significantly improved assumptions of normality. Pearson product-moment correlation was used to assess associations between deprivation and accessibility of greenspaces.

Generalised Linear Mixed Models (GLMMs) were used to identify potential variables that might explain differences in levels of physical inactivity between LSOA populations. In all models, inactivity was a two-vector response variable of the number of active, and inactive, people in an LSOA. To account for the fact that physical activity in the population was a proportion, while taking into account the varying population size of LSOAs, we used a binomial error structure. To represent access, two ANGSt (areas over 2 ha within 300 m, and areas over 20 ha within 2 km) greenspace proximity/accessibility standards, were incorporated as predictors. The larger ANGSt were not modelled, due to the errors associated with not having greenspace data from beyond the Kent boundary, and as physical activity is most likely to take place in sites closer to people's homes (Natural England, 2015). The models also included three known predictors of physical inactivity from the scientific literature: (i) the proportion of the population over 65 years old (obtained from the 2011 census); (ii) the natural logarithm of the level of deprivation in the community (measured via the Index of Multiple Deprivation, 2015); and, (iii) the proportion of the population who are non-white (obtained from 2011 census).

Two 'random effects' were accounted for in the models. The first of these was differences between rural/urban LSOA population density and size (via the 2011 rural-urban classification; ONS, 2011b). The second was LSOA identity, included to control for overdispersion (greater variation in the dataset than would be expected by a binomial model without inclusion of this random effect) (Browne et al., 2005). Two erroneous data points (LSOA E01024563 Swale 015D and E01024683 Thanet 013B) were removed from dataset prior to conducting the analyses, as the number of inactive people was higher than the total population.

Collinearity between explanatory variables in each model was tested and deemed acceptable, as no variables had a variance inflation factor greater than three (Zuur et al., 2009). An information-theoretic approach to model selection was used to compare all candidate models and identify the most parsimonious solution (Burnham and Anderson, 2003; Whittingham et al., 2006). Only candidate models with a $\Delta AIC_C < 4$ (change in second order Akaike Information Criterion) were included in the model set used for model averaging and, as such, implausible models with low AIC weights were eliminated from the analysis solution (Bolker et al., 2009; Burnham and Anderson, 2003). Averaged parameter estimates (β), unconditional standard errors (SE), lower and upper 95% confidence intervals (LCI and UCI) and relative variable importance factors (RI) are reported for each GLMM.

To investigate if there are any differences in physical activity outcome, due to any perceived or actual differences in the environmental quality of sites, the statistical analyses were conducted for naturalness level 1 greenspaces, and then again for all naturalness level 1, 2 and 3 sites combined. Each model was also run for the population of Kent as a whole, and repeated for urban and rural Kent separately, to assess if these populations had different physical activity outcomes associated with greenspace access. All statistical analyses were performed using R (version 3.2.3; 2015) and GLMMs applied using the package lme4 (Bates et al., 2015).

6.4. Results

6.4.1. Proportion of population meeting accessibility standards

When considering all naturalness levels, only 13% of the population of Kent had access to greenspaces according to all four Accessible Natural Greenspace Standards (ANGSt). However, only 9% of the population of Kent did not meet any ANGSt (Table 6.4.; Figure 6.5.). The least well met standard across all naturalness levels was the most proximate/smallest accessibility standard, where only 34% of the population had a site of at least 2 ha within 300 m (Table 6.5.). The same relationship is apparent for naturalness level 1 sites, where the least met standard was access to a site at least 2 ha within 300 m, with only 15% of the population of Kent meeting this standard.

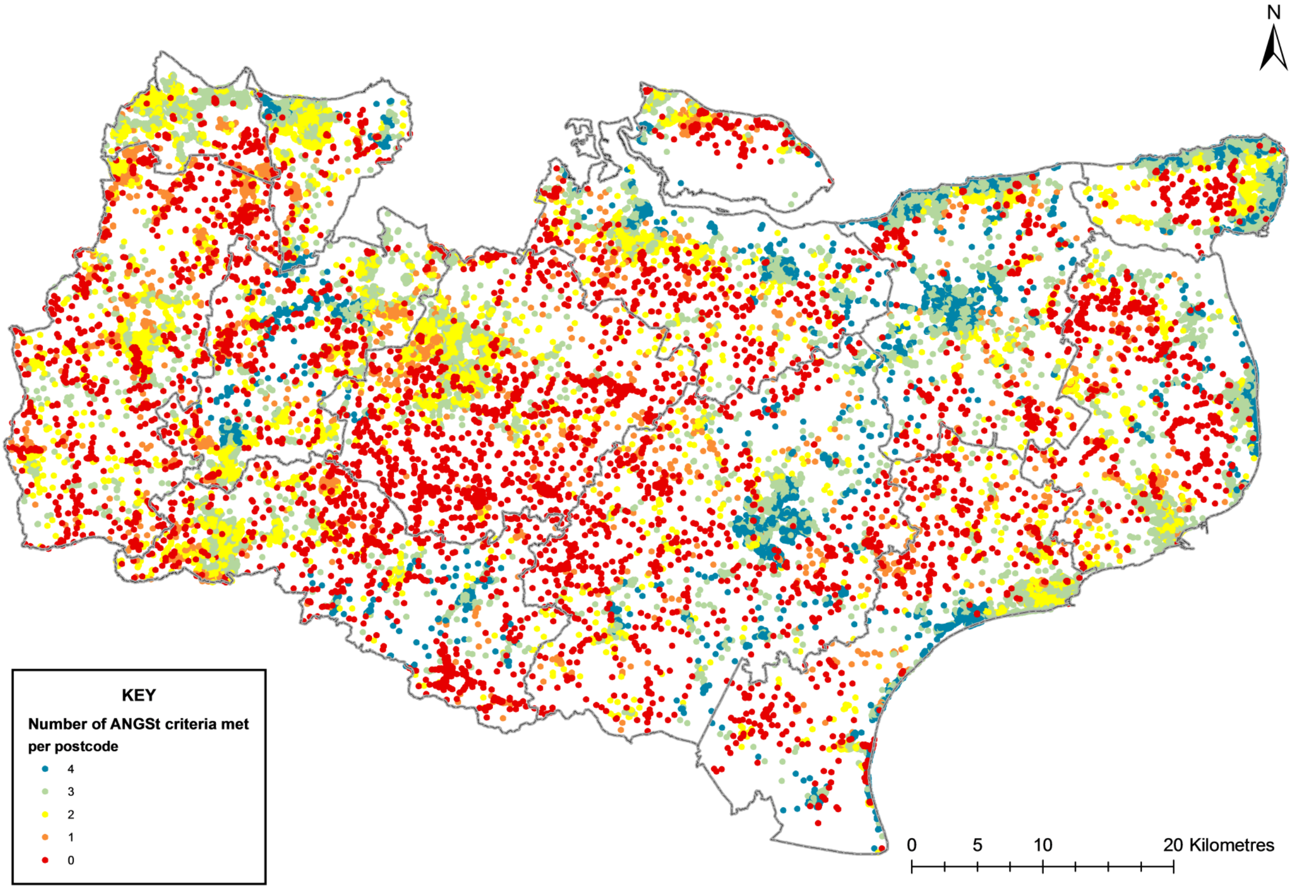

Figure 6.5. The number of Accessible Natural Greenspace Standards (ANGSt) criteria met per postcode in Kent.

Table 6.4. Percentage of population meeting multiple Accessible Natural Greenspace Standards (ANGSt) for all types of greenspace (naturalness levels 1, 2 and 3).

Number of ANGSt met	2 ha to <20 ha within 300 m	20 ha to <100 ha within 2 km	100 ha to <500 ha within 5 km	>500 ha within 10 km	No. of postcodes	Population	% total population	Households
0					**5493**	**137469**	**9%**	**54393**
1	X				479	16977	1%	6747
1		X			977	36134	2%	14497
1			X		1516	64805	4%	26368
1				X	333	8533	1%	3149
1 (any)	-	-	-	-	**3305**	**126449**	**8%**	**50761**
2	X	X			588	17547	1%	7103
2	X		X		490	20824	1%	8361
2		X	X		6596	287488	20%	119617
2	X			X	24	680	0%	277
2		X		X	99	3048	0%	1262
2			X	X	2835	127207	9%	51919
2 (any)	-	-	-	-	**10632**	**456794**	**31%**	**188539**
3	X	X	X		5199	211642	14%	89021
3	X		X	X	780	37087	3%	15216
3	X	X		X	72	1803	0%	740
3		X	X	X	7323	302996	21%	126751
3 (any)	-	-	-	-	**13374**	**553528**	**38%**	**231728**
4	X	X	X	X	**5193**	**189529**	**13%**	**80217**

Table 6.5. Percentage of population in Kent meeting Accessible Natural Greenspace Standards (ANGSt) according to naturalness levels.

Accessible Natural Greenspace Standards (ANGSt)	Naturalness levels 1, 2 and 3	Naturalness level 1
At least 1 site >2 ha within 300 m	34%	15%
At least 1 site >20 ha within 2 km	72%	64%
At least 1 site >100 ha within 5 km	85%	79%
At least 1 site >500 ha within 10 km	46%	44%

Comparisons were made of populations meeting accessibility standards in relation to naturalness level 1, 2 and 3 greenspace by rural-urban classification. For all accessibility standards, the overall percentage of people in rural villages and dispersed areas meeting the accessibility standards was lower than in urban areas and the rural town and fringe (Table 6.6.).

Table 6.6. Percentage of population by rural-urban LSOA classification across Kent meeting the Accessible Natural Greenspace Standards (ANGSt).

	ANGSt	Rural village and dispersed	Rural town and fringe	Urban city and town	Major conurbations
Naturalness 1, 2 and 3 sites	At least 1 site >2 ha within 300 m	23%	29%	37%	36%
	At least 1 site >20 ha within 2 km	46%	62%	82%	62%
	At least 1 site >100 ha within 5 km	51%	70%	93%	98%
	At least 1 site >500 ha within 10 km	34%	38%	51%	44%
Naturalness 1 sites	At least 1 site >2 ha within 300 m	14%	15%	16%	9%
	At least 1 site >20 ha within 2 km	42%	59%	74%	47%
	At least 1 site >100 ha within 5 km	46%	61%	91%	79%
	At least 1 site >500 ha within 10 km	32%	34%	49%	44%

A significant correlation (Pearson product-moment) was found between deprivation (the natural logarithm of the IMD score) and accessibility of naturalness level 1, 2 and 3 greenspace in LSOAs of: (i) at least 2 ha within 300 m (r_{898} = 0.09, $p < 0.01$); (ii) at least 100 ha within 5 km (r_{898} = 0.19, $p < 0.001$); and, (iii) at least 500 ha within 10 km (r_{898} = 0.24, $p < 0.001$). A statistically significant correlation was not found with deprivation for sites of at least 20 ha within 2 km (r_{898} = 0.02, p = n.s.). A significant but weak correlation was found between deprivation and accessibility to naturalness level 1 for greenspace of: (i) at least 100 ha within 5 km (r_{898} = 0.14, $p < 0.001$) and (ii) at least 500 ha within 10 km (r_{898} = 0.23, $p < 0.001$). This was not the case for sites of at least 2 ha within 300 m (r_{898} = -0.02, p = n.s.) or at least 20 ha within 2 km (r_{898} = 0.02, p = n.s.).

6.4.2. Predictors of physical inactivity

GLMMs described potential variables that might explain differences in levels of physical inactivity between LSOA populations. In all models, both IMD score and the proportion of the population over 65 years old were significantly and positively related to inactivity in LSOAs. The proportion of the population who record their ethnicity as non-white was not significantly related to inactivity levels in any model (Table 6.7. and Table 6.8.).

For all naturalness level 1, 2 and 3 sites combined, the proportion of the population meeting the two ANGSt were not related to inactivity levels in LSOAs (β = -0.08, 95%CI = -0.27, 0.10 for a site > 2 ha within 300 m; β = -0.12, 95%CI = -0.31, 0.06 for a site > 20 ha within 2 km) (Table 6.7.). When modelled separately, these results were consistent for both urban (Table S6.7.3.) and rural (Table S6.7.4.) LSOAs.

Table 6.7. GLMM statistical output exploring potential explanatory variables of physical inactivity in Kent. The Accessible Natural Greenspace Standards (ANGSt) relate to greenspace categorised as naturalness levels 1, 2 or 3. Significant explanatory variables (where the confidence intervals do not cross zero) are highlighted in bold. The other listed variables do not predict physical inactivity.

Response	Explanatory variable	β	SE	LCI (2.5%)	UCI (97.5%)	RI
Proportion of the population physically inactive $N_{inactivity}$ = 900 All Kent LSOAs	(Intercept)	-1.99	0.53	-3.04	-0.95	
	Proportion of population with access to a site over 2 ha within 300 m	-0.08	0.09	-0.27	0.10	0.35
	Proportion of population with access to a site over 20 ha within 2 km	-0.12	0.10	-0.31	0.06	0.45
	Index of multiple deprivation (natural logarithm)	**1.64**	**0.09**	**1.46**	**1.83**	**1.00**
	Proportion of population over 65 years old	**1.88**	**0.11**	**1.68**	**2.09**	**1.00**
	Proportion of the population non-white	-0.21	0.12	-0.45	0.03	0.61

β = averaged parameter estimates; SE = unconditional standard errors; LCI = Lower confidence interval (2.5%); UCI = upper confidence interval; RI = relative variable importance factor

When considering ANGSt for naturalness level 1 sites across the entire county (Table 6.8A), Figure 6.6), the proportion of the population with access to a site over 2 ha within 300 m was significantly and negatively related to physical inactivity (β = -0.20, 95%CI = -0.39, -0.02). However, a similar relationship was not apparent for sites over 20 ha within 2 km (β = -0.12, 95%CI = -0.31, 0.08). The same patterns were observed when just urban LSOAs were considered (Table 6.8B), with levels of physical inactivity reducing as more people in a population have access to greenspace over 2 ha within 300 m (β = -0.21, 95%CI = -0.42, -0.00). When only rural LSOAs were examined, the proportion of the population meeting either ANGSt failed to predict physical inactivity for either accessibility standard (β = -0.22, 95%CI = -0.60, 0.17 for a site > 2 ha within 300 m; β = -0.02, 95%CI = -0.43, 0.39 for a site > 20 ha within 2 km) (Table 6.8C). This indicates that the relationship found between access to naturalness 1 sites over 2 ha within 300 m in the whole of Kent is primarily driven by urban populations.

Table 6.8. GLMM statistical output exploring potential explanatory variables of physical inactivity in Kent. The Accessible Natural Greenspace Standards (ANGSt) relate to greenspace categorised as naturalness level 1. Significant explanatory variables (where the confidence intervals do not cross zero) are highlighted in bold. The other listed variables do not predict physical inactivity.

Response	Explanatory variable	β	SE	LCI (2.5%)	UCI (97.5%)	RI
Model A. All Kent LSOAs	(Intercept)	-1.99	0.53	-3.03	-0.97	
	Proportion of population with access to a site over 2 ha within 300 m	**-0.20**	**0.09**	**-0.39**	**-0.02**	**0.82**
Proportion of the population physically inactive	Proportion of population with access to a site over 20 ha within 2 km	-0.12	0.10	-0.31	0.08	0.43
	Index of multiple deprivation (natural logarithm)	**1.64**	**0.09**	**1.46**	**1.82**	**1.00**
$N_{inactivity}$ = 900	**Proportion of population over 65 years old**	**1.88**	**0.10**	**1.68**	**2.09**	**1.00**
	Proportion of the population non-white	-0.21	0.12	-0.45	0.03	0.63
Model B. Urban LSOAs	(Intercept)	-1.22	0.18	-1.58	-0.87	
Proportion of the population physically inactive	**Proportion of population with access to a site over 2 ha within 300 m**	**-0.21**	**0.10**	**-0.42**	**-0.00**	**0.75**
	Proportion of population with access to a site over 20 ha within 2 km	-0.17	0.11	-0.40	0.04	0.59
$N_{inactivity}$ = 651	**Index of multiple deprivation (natural logarithm)**	**1.65**	**0.11**	**1.44**	**1.85**	**1.00**
	Proportion of population over 65 years old	**1.89**	**0.12**	**1.66**	**2.12**	**1.00**
	Proportion of the population non-white	-0.23	0.14	-0.50	0.05	0.58
Model C. Rural LSOAs	(Intercept)	-2.73	0.59	-3.91	-1.56	
Proportion of the population physically inactive	Proportion of population with access to a site over 2 ha within 300 m	-0.22	0.19	-0.60	0.17	0.40
	Proportion of population with access to a site over 20 ha within 2 km	-0.02	0.21	-0.43	0.39	0.21
$N_{inactivity}$ = 249	**Index of multiple deprivation (natural logarithm)**	**1.60**	**0.19**	**1.22**	**1.98**	**1.00**
	Proportion of population over 65 years old	**1.69**	**0.19**	**1.32**	**2.07**	**1.00**
	Proportion of the population non-white	0.00	0.20	-0.40	0.40	0.20

β = averaged parameter estimates; SE = unconditional standard errors; LCI = Lower confidence interval (2.5%); UCI = upper confidence interval; RI = relative variable importance factor

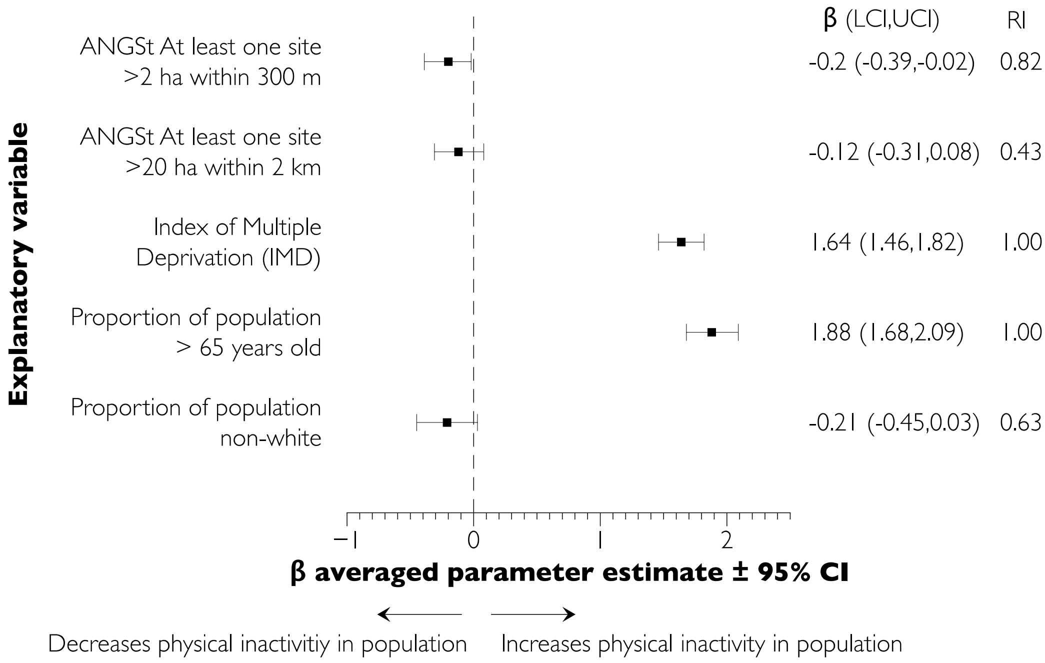

Figure 6.6. GLMM statistical output exploring potential explanatory variables of physical inactivity in Kent (From Table 6.8). The Accessible Natural Greenspace Standards (ANGSt) relate to greenspace categorised as naturalness level 1. Significant explanatory variables are where the confidence intervals do not cross zero. The other listed variables do not predict physical inactivity. β = averaged parameter estimates; LCI = Lower confidence interval (2.5%); UCI = upper confidence interval; RI = relative variable importance factor

6.5. Discussion

6.5.1. Provision of greenspaces

We found an under provision of accessible natural greenspace according to government criteria (ANGSt), especially at the most proximate and close standard, where only 35% of the population of Kent have access to at least one site over 2 ha within 300 m of their home. This is comparable to findings from other English counties (Natural England, 2014). We found there to be less access to sites that are categorised to have a higher level of 'feeling of naturalness'. This disparity in access between sites of lower and higher naturalness is especially apparent for the smaller area size standard, because sites that are categorised as more natural (i.e. sites designated for nature conservation) were typically larger in size.

It is important to caveat these results with the limitations of the underlying data, the 'feelings of naturalness' categorisation outlined in the ANGSt guidance, is relatively rudimentary for the purposes of understanding differences between the effects of different environments. This is especially so given recent more nuanced evidence on how different natural environments effect people's perception of 'naturalness' and how these lead to well-being and health outcomes (MacKerron and Mourato, 2013; Wheeler et al., 2015; Seresinhe et al., 2017). Given this recent evidence, it is unlikely that the levels of naturalness in the original ANGSt guidance is an appropriate basis for policy, and future evidence-based accessibility metrics should take this into account (Ekkel and de Vries, 2017).

6.5.2. Greenspace access and physical activity

We did not find an association between physical activity and access to greenspace of all naturalness levels. However, we did find an association between physical activity and access to at least one site over 2 ha within 300 m, when just considering sites of a higher naturalness within urban areas. This indicates that this effect may be specific to certain populations and types of greenspaces. This is in accordance with other studies who did not find a link between greenspace access/availability and physical activity, or found a complex relationship (Hoehner et al., 2005; Hillsdon et al., 2006; Annerstedt et al., 2012). For example, Mytton et al. (2012) found higher levels of physical activity in neighbourhoods with more greenspace. However, when distinguishing between activity types, they found this to be due forms of exercise not associated with the use of public greenspace, such as gardening and home improvement. A longitudinal study in Australia found no association between local greenspace attributes and the initiation of walking, but did find a significant association between positive perceptions of the presence and proximity of greenspace, and maintaining walking behaviours over time (Sugiyama et al., 2013). In context of this complexity, the specificity of our finding concerning close, more natural sites and urban populations, could be due to the relatively low level of contact these populations already have with nature. However, this is something we were unable to test with our current data.

Although the measure of activity we used did not establish actual rates of greenspace use, a recent survey across the whole of England indicated that 68% of visits to ‘nature’ took place within 2 miles (3.2 km) of people’s homes (Natural England, 2015). It could therefore be assumed that residential proximity would be related to the frequency of visits. The significance of close spaces is unsurprising, as previous studies have found that people are more likely to visit greenspaces close to where they live (Giles-Corti et al., 2005; Carter and Horwitz, 2014; Dallimer et al. 2014). As ANGSt criteria considers site area and proximity simultaneously, this means that the relative importance of these two factors are not readily disentangled. Additionally, the density of greenspaces around a human population (not just the distance to the closest available space) may also be a relevant metric (Ekkel and de Vries, 2017). Wheeler et al. (2015) found positive associations with good health prevalence, by considering the percentage of land cover of different types within LOSAs. Although we found an association with small spaces above 2 ha in size, sites even smaller may also play a role in promoting physical activity. Others have emphasised the importance of ‘pocket parks’ for health and well-being, even if not used for more moderate types of activity (Nordh et al., 2009; Peschardt et al., 2012). Therefore, future research should compare different ways of quantifying size, distance, and quality of sites and how combinations of these factors influence health outcomes, and this would help to directly inform the development of appropriate metrics for policy (WHO, 2016).

Additional evidence is needed to understand how to motivate people to take part in physical activity within existing greenspaces, and should be considered in the design of appropriate social prescriptions. Factors such as fear of crime (Maruthaveeran and Bosch, 2014; Edwards et al., 2015), safety (Ali et al., 2017), opportunities for social interactions (Maas, 2009), and availability of facilities (Ries et al., 2008) are known to influence an individual's motivations for visiting greenspaces. Yet, a knowledge gaps still exists in the amount to which these features may interact with, and moderate physical activity levels in greenspaces.

6.5.3. Conclusions and implications

Physical activity promotes physical and mental health across the life span (Bize et al., 2007; Janssen and LeBlanc, 2010). Our study contributes to research into the potential environmental factors that influence population levels of physical activity, and ultimately therefore, health outcomes. We found estimated physical activity levels in the population to be associated with access to a subset of the most small, close, greenspaces within urban areas, but did not find an association for all types of greenspace. This suggests that the influence of greenspace availability on physical activity levels may be variable between human contexts and environmental quality. However, these results are caveated by the limitations in the underlying data. Experimental and longitudinal studies are needed to establish causality and further investigate the underlying mechanisms. For the development of policy, improved empirical accessibility metrics that are more appropriate to the way people use and experience sites are required.

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6.7. Supporting Information

Table S6.7.1. All datasets used within greenspace accessibility analysis

Type	Dataset	Data owner	Notes
Boundary	Kent and Medway	Ordnance Survey	Open data licence
	Districts	Ordnance Survey	Open data licence
	Clinical Commissioning Group (CCG)	NHS England	Open Government Licence
	Lower-layer Super Output Area (LSOA)	Office for National Statistics	2011 iteration
Greenspace	Nationally designated sites (Sites of Special Scientific Interest and National Nature Reserves)	Natural England	Open Government Licence
	Local Nature Reserves	Natural England	Open Government Licence
	Kent Wildlife Trust Reserves	Kent Wildlife Trust	Held by KMBRC not to be shared, only publicly open sites included
	Local Wildlife Sites	Kent Wildlife Trust	Held by KMBRC not to be shared
	Woodland Trust Reserves	The Woodland Trust	Held by KMBRC not to be shared
	RSPB Reserves	Royal Society for the Protection of Birds	Held by KMBRC not to be shared
	National Trust properties	The National Trust	Held by KMBRC not to be shared
	Kent Habitat Survey	Kent County Council	BAP priority habitats, woodlands and non-tidal coastal habitats used. 2012 iteration
	Kent County Council Country Parks	Kent County Council	Country Parks, picnic sites and other accessible natural spaces
	Registered Historic Parks and Gardens	Kent County Council	Not all open to the public
	Millennium Greens	Natural England	Open Government Licence
	Doorstep Greens	Natural England	Open Government Licence
	Forestry Commission woodland	The Forestry Commission	Open Government Licence
	Common land	Kent County Council	
	Open access land	Natural England	Open Government Licence
	Village greens	Kent County Council	
	Open space audit datasets		Not all PPG17 typologies were represented in all datasets
	Ashford	Ashford Borough Council	
	Canterbury	Canterbury City Council	
	Dartford	Dartford Borough Council	
	Dover	Dover District Council	
	Gravesham	Gravesham Borough Council	
	Maidstone	Maidstone Borough Council	
	Sevenoaks	Sevenoaks District Council	
	Shepway	Shepway District Council	
	Swale	Swale Borough Council	
	Thanet	Thanet District Council	
	Tonbridge and Malling	Tonbridge and Malling Borough Council	

	Tunbridge Wells	Tunbridge Wells Borough Council	
Access	Public Rights of Way	Kent County Council	
	Cycling routes	Kent County Council	
	Promoted cycle routes	Kent County Council	
	Roads with footways	Kent County Council	
Kent population data	Deprivation levels by LSOA	Department for Communities and Local Government	Open Government Licence
	Physical inactivity prevalence at Output Area	Kent County Council	
	Health datasets relating to conditions that may be improved by access to outdoor greenspace	Kent Health Observatory	
	Population at LSOA by, for example, age, sex, deprivation (IMD and domains) and ethnicity	Department for Communities and Local Government	
	Population data for postcodes	Office for National Statistics	Open Government Licence

Table S6.7.2. Experian Mosaic groups from which the physically inactive population figures were derived. Due to commercial licence restrictions, these five Experian Mosaic segments were grouped by Kent County Council prior to supplying the produced dataset.

Inactive Segments	Kent Population (No. of people)	Kent Population (%)
Segment 1: Residents aged 55 and over on low incomes, often living in social housing	66,947	4.5
Segment 2: Younger Residents on Low Incomes Living in Social Housing (Aged 20-50)	15,758	1.1
Segment 3: Comfortably off singles and couples aged over 55	241,128	16.1
Segment 4: Families on low incomes with school age children, many living in areas of high deprivation	34,780	2.3
Segment 5: South Asian singles aged 55+ who own their own home	3,228	0.2
Total	**361,841**	**24.2**

Table S6.7.3. GLMM statistical output exploring potential explanatory variables of physical inactivity in urban LSOAs in Kent. The ANGSt relate to greenspace categorised as naturalness levels 1, 2 or 3. Significant explanatory variables (where the confidence intervals do not cross zero) are highlighted in bold. The other listed variables do not predict physical inactivity.

Response	Explanatory variable	β	SE	LCI (2.5%)	UCI (97.5%)	RI
Proportion of the population physically inactive $N_{inactivity}$ = 651 Urban LSOAs	(Intercept)	-1.21	0.19	-1.59	-0.83	
	Proportion of population with access to a site over 2 ha within 300 m	-0.13	0.10	-0.34	0.06	0.46
	Proportion of population with access to a site over 20 ha within 2 km	-0.16	0.11	-0.37	0.04	0.53
	Index of multiple deprivation (natural logarithm)	**1.65**	**0.11**	**1.45**	**1.86**	**1.00**
	Proportion of population over 65 years old	**1.89**	**0.12**	**1.66**	**2.12**	**1.00**
	Proportion of the population non-white	-0.23	0.14	-0.50	0.04	0.57

Table S6.7.4. GLMM statistical output exploring potential explanatory variables of physical inactivity in rural LSOAs in Kent. The ANGSt relate to greenspace categorised as naturalness levels 1, 2 or 3. Significant explanatory variables (where the confidence intervals do not cross zero) are highlighted in bold. The other listed variables do not predict physical inactivity.

Response	Explanatory variable	β	SE	LCI (2.5%)	UCI (97.5%)	RI
Proportion of the population physically inactive $N_{inactivity}$ = 249 Rural LSOAs	(Intercept)	-2.73	0.59	-3.91	-1.56	
	Proportion of population with access to a site over 2 ha within 300 m	0.09	0.20	-0.30	0.47	0.23
	Proportion of population with access to a site over 20 ha within 2 km	-0.08	0.20	-0.47	0.30	0.23
	Index of multiple deprivation (natural logarithm)	**1.60**	**0.19**	**1.22**	**1.98**	**1.00**
	Proportion of population over 65 years old	**1.69**	**0.19**	**1.30**	**2.07**	**1.00**
	Proportion of the population non-white	-0.01	0.20	-0.41	0.39	0.16

Chapter 7. General discussion

This thesis aimed to investigate, through a series of case studies, what individuals perceive, prefer and value about characteristics of the natural world, and how these factors may lead to outcomes for human health and well-being. This is done by employing interdisciplinary methodologies, from ecology, public health, economics and the social sciences, through the lens of conservation science. Explored within these studies is the potential for win-win and trade-off situations in interventions designed for biodiversity conservation and human well-being. Understanding what individuals perceive as constituting a preferable biodiverse environment will allow for human-modified landscapes to be designed in a manner that delivers maximum benefits to people and biodiversity. Further, at a time of increasing human impacts on natural systems, understanding how and why people value different aspects of ecological systems can allow managers to act to minimise conflicts and promote the social acceptability of management activities (Ives and Kendal, 2014). This general discussion summarises the key contributions to knowledge of the studies within this thesis and their aggregate contribution to a wider body of knowledge and considers their implications for conservation and other disciplinary research perspectives.

7.1. The components of nature that people perceive, value and gain benefit from

Despite a growing body of evidence, across multiple disciplines, describing human-nature interactions and the benefits people gain from these interactions (Keniger et al., 2013; Ives et al., 2017), little is known about how people perceive, value and benefit from specific components or characteristics or biodiversity. In research into ecosystem services, species richness is the most frequently used unit of measurement (e.g. Feld et al., 2009; Schwarz et al., 2017), however, it is unclear, and unlikely, that the number of species alone is the most relevant measure to link biodiversity to human preferences and cultural ecosystem services. Understanding which features are most germane to people is important, especially for ecosystem management in urban areas, so spaces can be designed, planned and managed to maximise the benefits people gain from interacting with nature, and therefore ensuring the long-term sustainability of ecological systems alongside people.

Chapter 2, “Unpacking the people-biodiversity paradox: a conceptual framework”, brought together much of the current the literature (up to 2016, when published) on people-nature interactions. Here I described a mismatch identified in a number of published studies between people’s biodiversity preferences and how they relate these preferences to their subjective well-being and ability to perceive biodiversity. A distinctive point observed from this literature, is that the outcome of interactions between people and nature are often influenced by complex factors beyond any immediate objective ecological measures that conservation biologists observe, or would have an interest in. Thus, simply observing ecological characteristics of sites, such as the abundance or richness of species, or presence of particular species, is unlikely to alone unlock the underlying link between biodiversity and self-reported human health and well-being. Therefore, it is just as important to understand what individuals perceive as constituting a preferable biodiversity environment and what influences this perception, as it is to directly measure the biodiversity they experience. Therefore, in further chapters I combined the quantification of biodiversity characteristics with measures of individuals' perceptions of, and values for, these characteristics.

The described people-biodiversity paradox is illustrated further within this thesis through the results of the wildflower meadows studies (**Chapters 4 and 5**). In these studies, people's preferences for, and perceptions of, wildflower meadows sown in urban greenspaces in the UK was explored and quantified. In **Chapter 4,** biodiversity surveys established the diversity and abundance of flowering plants and pollinators at the wildflower meadows, whilst at the same time responses to questionnaires were collected *in situ* at the sites. As could be predicted, the intervention of sowing wildflower meadows, increased the species richness of both the plants and the pollinating insects found at the sites, above that of amenity grass. **Chapter 4** found that people could broadly perceive the species richness of plants and found an association between perceived richness and people's rating of the colourfulness of sites. However, when interrogating the magnitude of people's preferences for different characteristics of biodiversity in the flower meadows, through the use of a choice experiment (**Chapter 5)**, species richness was the characteristic for which people expressed the least preference. Thus, although people were able to perceive a particular component of biodiversity of interest to conservationists, this was not core to people's values towards meadows. Although people did not state a significant preference for higher plant species richness, they did express preferences for other characteristics. For instance, people expressed a willingness-to-pay for sites that had a higher proportion of native species, and those described as having a higher quality for pollinating insects. The latter of these is a particularly interesting finding, as invertebrates can sometimes be considered unattractive to people (e.g. McGinlay et al., 2017). However, I speculate that this preference for pollinators in particular may stem from recent publicity on the plight of insect pollinators, and a public concern about the need to avoid declines in pollinators and pollinator services (Breeze et al., 2015; Wilson et al., 2017). Further research could investigate this as a potential success story in conservation messaging. As was found in a similar study on urban flower meadow planting (taking a different approach to measuring values; Southon et al., 2017), people appear to value the ecological function that meadows can provide to pollinators, and prefer, or at least could be willing to tolerate, ‘messy’ planting they deem less attractive if aware of these benefits. Although in these studies I was primarily investigating the environmental factors that people value and prefer from the perspective of cultural ecosystem services, similar techniques have increasingly been used within conservation marketing (e.g. Veríssimo et al., 2013; Lundberg et al., 2019). This field is interested in understanding the characteristics of species (e.g. flagship species) and ecosystems that people prefer, so these can be promoted to maximise potential support and fundraising for conservation (Smith et al., 2012). However, conservation marketing could have the potential to act in changing people’s perceptions of biodiversity and conservation issues more broadly, using similar methodologies to the ones used in **Chapters 3 and 5** to identify the most effective and relevant campaigns.

Whether people are able to perceive differences between areas of low/high biodiversity has received mixed results in the literature. Some have found that people can broadly correctly perceive differences in species richness (Fuller et al., 2007; Lindemann-Matthies and Marty, 2013; Qiu et al., 2013), whereas others have not found this (Dallimer et al., 2012; Shwartz et al., 2014). The findings of **Chapter 4** are comparable to this mixed view, in that, in general people’s perception of plant species richness was related to the true floral richness, but that people consistently underestimated the richness of meadow sites with a greater richness and overestimated the richness of less biodiverse amenity grass control sites. Further, unsurprisingly, people’s rating of the colour of sites was higher for meadows vs. control sites, and therefore related to higher floral abundance, richness and diversity; but when considering differences just between meadows sites, this relationship was not found. This indicates that perhaps the scale of change we were investigating between plots may not have been large enough to be perceptible to individuals, and thus people may be able to perceive broader differences between sites, but not between plots within sites. The appropriate biodiversity scale at which to conduct biodiversity perception and valuation studies (from genes up to ecosystems) is still unclear. However, in general, evidence of the linkages between biodiversity and cultural ecosystem services is less conclusive at smaller scales (Botzat et al., 2016) and this study fits this pattern.

Some measures of connectedness-to-nature have been found to be associated with health and subjective well-being outcomes (Capaldi et al., 2014), as well as being predictive of pro-environmental behaviour (Richardson et al., 2016). In **Chapter 4**, a state-based indicator of connectedness-to-nature (CNS) was used to test if any immediate ecological factors associated with the site that people were next to, or individual’s perceptions of sites, was associated with CNS. When controlling for other factors, no immediate site characteristics predicted individual's CNS, and the only characteristic pertaining to the site to do so was individual's rating of the colourfulness of the meadows. Differences in CNS state have been found between broadly defined 'natural' and 'urban' settings (Mayer et al., 2009), and the overall environmental quality of sites (Wyles et al., 2019). Therefore, as the scale of environmental change measured in this meadows study was much narrower (i.e. the number of species present vs. a completely different environmental context), this may explain the differences between these results. Therefore, it cannot be assumed that increases in the ecological quality of sites will lead to increases in people's connectedness-to-nature, and similar to the conclusions of **Chapter 2**, certain cues, such as people's perceptions of the colourfulness of sites, are important to consider beyond the ecological characteristics of a site. Differences between individual's are also important to consider. Like others (Luck et al., 2011; Cervinka et al., 2012), we found older people to have a higher CNS score. Additionally, people who took more trips to the natural environment had a higher CNS, which could indicate a virtuous circle between connectedness-to-nature and contact with nature. However, with each of these, it is not possible to truly establish causality through the approach taken within the study, and longitudinal studies that track the same individuals over time are needed to assess how relationships with the natural world change through age and experiences. Interestingly, CNS scores did have a tangible impact upon people's valuation of different characteristics of meadows (**Chapter 5**), and those with a higher CNS score had a significantly higher willingness-to-pay for meadows of a high quality for pollinating insects, and for more colourful meadows. Therefore, the extent of people's emotional connection to the natural world (whether a 'trait' or a 'state') may translate to real-world implications in regard to support and acceptance of ecological interventions.

Chapter 3 investigated human-nature relationships from a different perspective, through the lens of preferences towards management of native and non-native invasive species. The study has practical implications regarding people's preferences towards invasive species management and also contributes towards to the evidence of which characteristics of biodiversity people possess values towards. Firstly, in this study we found that the concept of 'nativeness' of a species was not a major concern to people's preferences towards management of species (framed as 'pests'), with few differences between the preferences of the cohort of people for whom the status of the species as native was explicitly stated, vs. those for which this was not stated. This is in contrast to **Chapter 5,** wherein people expressed a preference towards flower meadows that contain a greater proportion of native species. These differences could be due to differing values for taxa that are deemed charismatic or not (Lorimer, 2007). However, common to both the bird and flower meadows studies is the relatively low level of knowledge the respondents had when asked to assess the proportion of species that were native (**Chapter 4**) or whether they were aware of the concept of nativeness at all (**Chapter 3**). Another key finding of **Chapter 3** was that exposure to, or experience of, a species, measured by a person indicating that they had seen ring-neck parakeets in their city, influenced their preferences towards management action to be taken for that species. This is an important finding, as when invasive species spread and become more common in areas, it is likely that resistance to their management will increase as people gain more contact with them. Related to this, is the finding that the aesthetic appeal of species was important to people's judgement on their management. Indeed, these results suggest that public opposition to management, and their tolerance of any negative impacts of species, are both likely to be greater for species that people find more appealing.

In **Chapter 6**, associations between physical activity levels of small populations and accessibility to greenspaces was explored, with a specific focus on how 'naturalness' as measured by the government recommended guidelines, impacted this relationship. Lack of physical activity directly contributes to one in six deaths in the UK, approximately the same proportion as caused by smoking tobacco (PHE, 2014). Therefore, if access to natural environments can play even a small role in promoting exercise this would be of interest to public health. In accordance with other studies (e.g Hoehner et al., 2005; Hillsdon et al., 2006; Mytton et al., 2012); we did not find a consistent relationship between population level physical activity and access to greenspaces. In fact, a positive association with higher physical activity levels was only found between the accessibility standard representing the closest, smallest spaces of the highest naturalness level, and this was only within urban areas. Also of note is the relatively small effect size that this result had, compared to factors of deprivation level and age. Therefore, overall the study is inconclusive on the contribution of the 'naturalness' of areas to physical activity levels and it is likely that many other factors (both biophysical and social) beyond sites' statutory designation for nature, likely impact upon the uptake of physical activity.

Taken together, the findings of these studies indicate that people's perceptions and values towards nature, and therefore the supply of cultural ecosystem services, are only partially related to ecological characteristics (such as species richness, and species identity). Aesthetics, cultural factors, characteristics of people (such as their individual experiences and knowledge) and how ecological management is framed, play a large role in people's perceptions and values and must therefore be considered within wider planning and valuation of ecosystems.

7.2. Win-wins and trade-offs between human values and preferences and conservation of biodiversity

Within conservation science, determining the best way to conserve biological diversity whilst meeting the needs of people has led to lively debate. Policies that protect biodiversity by completely isolating it from humans are likely to fail to encourage the public support necessary for the long-term conservation of biodiversity (Brockington et al., 2006). Yet, on the contrary, biodiversity that is managed only for human well-being may not necessarily constitute the type of healthy, dynamic, evolutionary ecosystems biodiversity conservationists wish to protect. Therefore, particularly in urban areas where humans dominate, human preferences and values must be understood and considered in order to minimise conflicts and promote social acceptability (Ives and Kendal, 2014; Clayton et al., 2017). Ongoing land-sparing vs. land sharing debates on how best to grow the world's cities whilst ensuring the supply of ecosystem services (Lin and Fuller, 2013; Soga et al., 2014) would also benefit from more nuanced information on people-biodiversity relationships within urban areas.

Human-nature interactions, and their consequences for human health and well-being have sometimes been framed as a 'missing ecosystem service', that has been undervalued or overlooked, with the potential for directly leveraging investment in biodiversity (Hughes et al., 2013). However, whether there are true win-win scenarios in promoting biodiverse environments in the places that people live and work is still unclear. If, as **Chapter 2** concludes, and the results of **Chapter 4** corroborates, the outcome of human-biodiversity interactions are influenced by people's perceptions of biodiversity rather than by objective measures, then a goal of conservationists who wish to maximise these relationships could be to influence these perceptions. One way to do this would be to implement interventions that are simultaneously of high value to people, and to biodiversity. This type of win-win appears to be possible at least when it comes to flower meadows, as people value colour diversity alongside providing quality sites for pollinating insects (**Chapter 5**). This apparent win-win is achievable as the functional traits that pollinators respond to, are at least indirectly overlapping with human preferences. However, it is likely that this will not always be the case, and there are limits to how closely these two agendas can be aligned.

As aesthetic cues appear to be important to people's perceptions and values towards species and communities (as found in **Chapters 3, 4 and 5**), it is possible that these are not the biodiversity elements that conservationists wish to promote. This means that management decisions may be a trade-off between different opposing objectives. Indeed, as biotic homogenisation is a major threat in urban areas (McKinney, 2002), a particular concern is that people may possess values towards particularly charismatic non-native invasive species that threaten native species (Beever, et al., 2019). This appears to be the case within the studies constituting this thesis, whereby people were more opposed to the management of ring-necked parakeets, especially when they rated their aesthetic appeal more highly (**Chapter 3**). In the flower meadows studies, people did express a preference for more native planting (**Chapter 5**), but this was lower than their relative preference for other factors. People were unable to distinguish native meadows and rated the non-native meadows as more colourful (**Chapter 4**). These findings are an important contribution to a growing literature on the social dimensions of 'novel ecosystems' (e.g. Backstrom et al., 2018). Novel ecosystems describe modified natural systems that have crossed irreversible socioecological thresholds due to anthropogenic change. The proponents of the concept propose that it broadens the possibilities for conservation, widening the range of ecosystems that are deemed worthy of conservation effort (Hobbs et al., 2013). In contrast, critics claim that the concept is ill-defined and may promote laissez-faire attitudes to conservation and ecological restoration (Murcia et al., 2014). As decisions on how to approach the conservation of degraded or novel ecosystems is inherently values-based, understanding individual and social values on how well ecological novelty is tolerated is important (Ives and Kendal, 2014). Indeed, non-native species are a key component of novel ecosystems and are not inherently 'good' or 'bad'. Instead judgement of these species is predicated on the ecological context in which they are found and human perspectives. Therefore, providing more nuanced information on people's values regarding the management of these species is important.

Another area in which win-wins are increasingly promoted is in the goal of maximising multiple ecosystem services within one landscape. Whilst recognising the limitations of the underlying data, in **Chapter 6** an association was found between access to small close greenspaces and physical activities. Such findings may provide an argument for the greater promotion of access to natural areas around people, either through increasing physical access, or through promoting an increase in the use of spaces. However, this needs to be carefully considered for greenspace managers who wish to maximise the ecosystem service value and biodiversity of sites. Increases in the recreational use of ecologically sensitive areas could lead to degradation of those sites, and therefore pose a conflict between different ecosystem services and biodiversity goals. Further, whilst having a network of smaller greenspaces closer to people's homes may be the best way to promote physical activity, this might be at odds with other greenspace functions. For example, it is likely that greenspaces need to be of considerable size for many species to persist. This pertains to wider debates on the optimal form of urban development that balances multiple competing ecosystem service and biodiversity needs (Lin and Fuller, 2013; Soga et al., 2014.). Taking into account why and where trade-offs occur is therefore more likely to create win-win scenarios than planning for win-wins from the offset (Howe et al., 2014). A systematic conservation planning framework can identify valuable synergies which can be included into decision making processes (Chan et al., 2006).

7.3. Contribution to interdisciplinary methodological development and validation

During the course of writing this thesis, this research topic area has seen an explosion of attention, and reviews of the topic identify the need the need for a greater integration of natural and multiple social sciences (Botzat et al., 2016; Ives et al., 2017). This thesis took an interdisciplinary perspective and employed methodologies from multiple disciplines, both across and within each constituent chapter. A key distinction to be made is that the research in this thesis has primarily used social science as a tool *for* conservation and has not taken the approach of being research *on* conservation. Therefore it has shared the normative mission of the discipline to ultimately contribute to the conservation of biodiversity (Sandbrook et al., 2013).

The semi-experimental designs within each chapter allowed for insights into people-biodiversity relationships that would not have been possible without taking such an approach. For example, in **Chapter 3**, I tested the effects of information provision and experience by using a crossed experimental design, stratifying which respondents received which information. Additionally, within **Chapters 4 and 5** the comparison of findings with a counterfactual allowed for differences between perceptions and values between different flower meadow and control sites to be evaluated. The direct comparison between ecological measurements and psychological/social outcomes within **Chapter 4** is an approach that has become more popular in recent years (e.g. Fuller et al., 2007; Dallimer et al., 2012), but one that is likely to become increasingly necessary to characterise how people encounter and experience other organisms as a ‘personalised ecology’ (Gaston et al., 2018).

One principal methodology used was the environmental economic approach of measuring stated preferences through choice experiments to unpack complex sets of values. Choice experiments were implemented in novel situations to gain deeper insights into people’s relative values for different characteristics of biodiversity and management. To my knowledge, these represent the first applications of this approach to the study of values towards the management of non-native invasive birds (**Chapter 3**), and to the creation of wildflower meadows (**Chapter 5**). A novel approach taken in **Chapter 5** was the implementation of a choice experiment *in situ* whilst respondents were 'experiencing' the environmental good they were valuing (i.e. some respondents were physically stood next to an urban flower meadow). Testing the effect of experience is not conventionally done within choice experiments and allowed us to unpack whether direct experiences made a difference to valuation. Related to this, **Chapter 3** tested whether people being directly 'exposed' to the environmental good they were valuing had an effect on values, by stratifying the sampling of the questionnaire respondents to areas with and without invasive parakeets. This type of approach of investigating the impacts of familiarity and experience on values is unusual within the economic valuation literature and only just receiving further attention (e.g. Jørgensen et al., 2013; Tabi and del Saz-Salazar, 2015).

Accessibility of greenspaces has traditionally been measured using Euclidean distances (i.e. the straight line between a household to the greenspace). This can be problematic as although some people may live in close proximity to greenspaces, the actual distance they need to travel to gain access to spaces is much further than would be identified by such an analysis. This may lead to the overestimation of access to greenspaces when accessibility metrics are applied in this. Therefore, in **Chapter 6**, a more accurate GIS model of human behaviour, and therefore the actual accessibility of sites, was tested by calculating the distance to travel to a greenspace entry point along pathways and pavements.

In **Chapter 4**, the environmental psychological connectedness-to-nature scale (CNS) was used to attempt to measure the effect of immediate environmental factors on people's 'state' of connection with nature. However, I failed to find any effect of site level environmental characteristics on CNS scores. As noted above, this could have been due to the scale of environmental change not being large enough to be measured by this particular instrument. However, it could be due to the tool itself also not being appropriate for the purpose for which it was used. Indeed, other researchers have questioned whether CNS, first developed for the measurement of a 'trait' can truly be applied to the measurement of experiential dimensions of human-nature interactions (Nisbet, et al., 2009). Yet others, through reliability testing and content analysis, have questioned whether the scale truly measures emotional connections at all, and rather measures cognitive beliefs (Perrin and Benassi, 2009). The reliability and validity of quantitative tools is a particularly tricky issue for interdisciplinary researchers who wish to apply 'off the shelf' solutions to the measurement of psychological constructs. Therefore, I would recommend to others to be cautious in their choice and application of CNS, and other similar, quantitative tools when attempting to measures dimensions of human-nature connections.

Finally, an approach not formally use much during this thesis was qualitative research techniques (except for the use of a some focus groups when designing the wider questionnaire of **Chapter 3**). This was partly because my research aims were to broadly understand and characterise how people perceived, valued and gained benefit from characteristics of biodiversity and therefore allow comparisons and generalisations to be made of human populations. Likewise, as I looked to combine measurements of quantitative biodiversity measures with human responses, using quantitative social measures allowed for commensurable comparisons. However, I also recognise that this decision was partly a pragmatic one, in not wanting to stray too far outside of my own disciplinary zone of comfort as a researcher. Qualitative information offers rich contextual understandings of topics and the exploration of complexity outside of the sometimes-narrower focus of quantitative research designs. Therefore, I would advocate for future research take a mixed methods approach to the study of human-nature interactions in order to gain the benefits of both quantitative and quantitative approaches.

7.4. Epilogue

Increasing land conversion for urbanisation and the rise of new technologies will undoubtedly bring further challenges for human-nature relationships and will likely have knock on implications for human health and well-being (Hartig and Kahn, 2016). Yet, rapid advancements in the studies of ecosystem services, ecological economics, ecological public health, environmental psychology and numerous other disciplines, alongside conservation science, bring more and more accurate, nuanced and inclusive representations of nature's contributions to people into decision making processes. Indeed, evidence such as that presented in this thesis enhances our understanding and can improve efforts to promote human well-being and conserve biodiversity.

Intriguingly, some scholars have argued that research into human-nature relationships could help inform transitional pathways towards sustainability, through identifying how to foster pro-environmental behaviour (Ives et al., 2017) and being one of a number of 'leverage points' for sustainability transformation (Abson et al., 2017). Conservation is ultimately about human behaviour (Schultz, 2011). However, evidence on how, and if experiences of nature, generate concern and support for conservation, and ultimately changes in behaviour is still nascent (Dean et al., 2019). If the 'extinction of experience' (Soga and Gaston, 2016), is to be reversed, conservationists must understand how to create the conditions for valuable experiences of nature (Clayton et al., 2016).

In his first speech as Secretary of State for Environmental, Food and Rural Affairs, Michael Gove, when setting out his vision for the UK's natural environment recognised the role that his early experiences in nature shaped his commitment to being an environmentalist: “I am an environmentalist first because I care about the fate of fellow animals, and I draw inspiration from nature and I believe that we need beauty in our lives as much as we need food and shelter. We can never be fully ourselves unless we recognise that we are shaped by forces, biological and evolutionary, that tie us to this earth that we share with others even as we dream of capturing the heavens.” (DEFRA, 2017). Time will tell whether the policies pursued by Gove will be positive for the UK’s natural environment. However, I think this exemplifies how policy makers are people too and demonstrates how individual personal experiences have the potential to ultimately lead to transformative change.

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Appendix 1. Online questionnaire on views towards bird species management (data used in Chapter 3).

This is one of 12 variations of this questionnaire originally produced in three languages, split between the provision of information about bird nativeness and two choice experiment 'blocks'. This is the English version, with the inclusion of nativeness information and choice experiment block 1.

Note, as originally hosted online some question elements are not perfectly aligned. Annotations to the survey are denoted by **<u>*bold underlined text</u>**

Appendix 1.1. Views on bird management questionnaire

Page 1: Consent

This questionnaire forms part of a project that is being carried out by a group of researchers from University of Kent, University of Leeds and University of Copenhagen. We are interested in understanding what preferences people have for the management of bird species in Europe. You are not required to have any specific knowledge or interest in the topic to complete the questionnaire. Your opinion still matters.

Will my answers be kept confidential?

Yes. You will be asked for some details regarding your personal circumstances (e.g. gender, age). However, these details will be entirely confidential. Your responses will be anonymised so they cannot be traced back to you personally. The findings of this research will be published in peer-reviewed scientific literature.

I understand that my participation is voluntary and that I am free to stop completing the questionnaire at any time

Yes, please continue ***<u>If respondents did not choose this option they would be 'screened out' of the questionnaire</u>**

Page 2: Eligibility

We first need to check that you are eligible to take part in this survey.

What is your country of residence?

Britain/Other

Page 3: Eligibility

How long have you lived in Britain?

Since birth/Less than/1 year/1 - 2 years/3 - 5 years/6 - 10 years/11 - 20 years/21 - 30 years/30+ years

What is your nationality? (***List of nationalities provided here**)

Which of these cities do you live in or nearby (if any)?

London/Bristol/Leeds/Other

Page 4: Your attitudes towards birds

We are interested in your views and attitudes towards pest bird species and how they should be managed. First of all, we would like you to answer a few simple questions.

Please rate how strongly you agree or disagree with the following three statements

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I enjoy listening to bird song					
I enjoy watching birds					
I find the noise made by some birds a nuisance					

In the last year have you used any methods to discourage birds from your home or garden (e.g. putting up nets, chasing, hand-clapping, shouting, using predator decoys)?

Yes/No

In the last year, have you fed birds in your garden/outdoor area?

Yes/No/I don't have access to a garden or outdoor area

If yes, how often do you provide food for birds?

Daily/Weekly/Monthly/Less than monthly/Never

Page 5: Do you recognise these bird species?

In this next section we will ask you about your views on the management of pest bird species. To begin with, please can you tell us how familiar you are with the following 6 bird species?

Branta canadensis

	Yes	No	Not sure
Do you recognise this species?			
Have you ever seen this species in the town/city where you live?			

Anser anser

	Yes	No	Not sure
Do you recognise this species?			
Have you ever seen this species in the town/city where you live?			

Page 6: Do you recognise these bird species?

Corvus corone

	Yes	No	Not sure
Do you recognise this species?			

Have you ever seen this species in the town/city where you live?			

Corvus splendens

	Yes	No	Not sure
Do you recognise this species?			
Have you ever seen this species in the town/city where you live?			

Page 7: Do you recognise these bird species?

Columba palumbus

	Yes	No	Not sure
Do you recognise this species?			
Have you ever seen this species in the town/city where you live?			

Psittacula krameri

	Yes	No	Not sure
Do you recognise this species?			

Have you ever seen this species in the town/city where you live?			

Page 8: Pest bird species in Britain

Over the following pages, we will ask you about your views on the management of bird species which are considered pests in one way or another. Pest birds can cause negative impacts by, for example, competing with other species for food or places to nest, damaging buildings, eating crops, and/or introducing diseases. The larger the size of a bird population, the more likely it is that negative impacts will occur.

Currently society spends money on managing pest birds to reduce the negative impacts. Management actions can include 'bird deterrents' (e.g. use of nets to protect crops/buildings, using lasers and noise machines to scare birds away) or 'lethal control' (e.g. shooting/gassing/poisoning adult birds, removing/damaging bird eggs). The 'current management' includes a combination of both 'bird deterrents' and 'lethal control'. These measures will all reduce the impact of birds and the damage they cause.

Can you think of any bird species that are pests?

Yes/No

If yes, please name the first species that you thought of:

Page 9: Native and invasive species in Britain

Some of the pests are 'invasive' and some are 'native'. The term 'invasive' refers to a pest species which has been introduced outside of where it occurs naturally and has the ability to spread geographically. 'Native' species live where they occur naturally.

Were you aware of the term 'invasive' species?

Yes/No

Were you aware that the definition only refers to species that do not occur naturally in Britain?

Yes/No

Can you think of any invasive species?

Yes/No

If yes, please name the first species you thought of:

Page 10: Managing pest bird species in the future

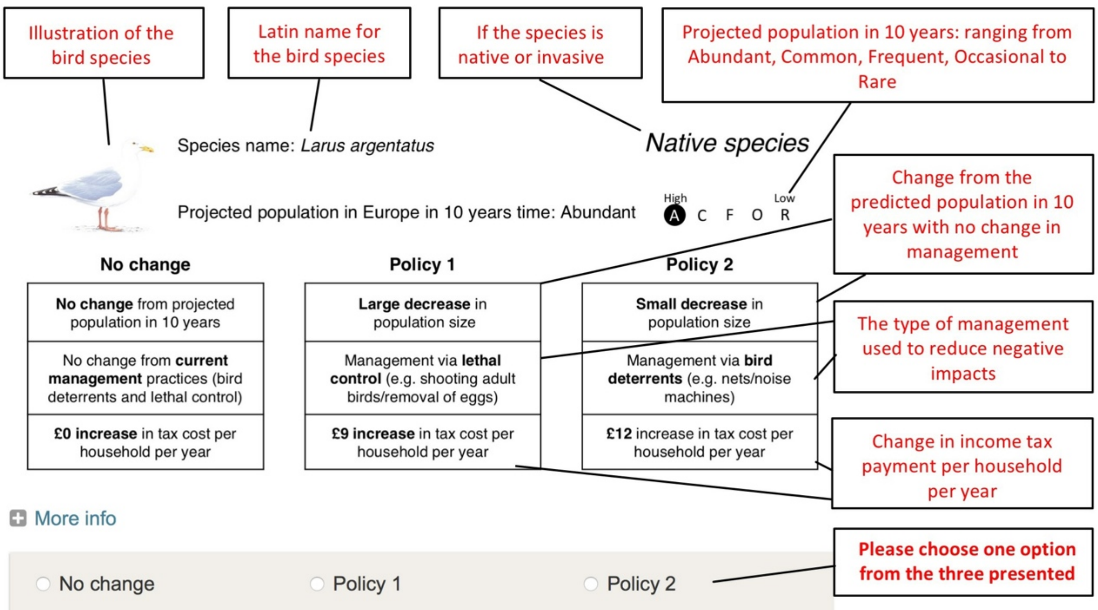
We are now going to ask if you would like to see a change in how society manages pest birds during the next ten years. Remember that all the birds we show you are pests in one way or another. Society therefore spends money each year on managing the negative impact of these birds. These costs are paid through your income tax.

The management of a pest bird species can be through 'bird deterrents', 'lethal control', 'current management' (a combination of 'bird deterrents' and 'lethal control'), or you may choose 'no management'. 'No management' means that all current management practices are stopped and money is spent on paying compensation for damage caused by the pest bird instead. However, do remember that larger populations will cause more damage. Despite their negative impacts, you may prefer that some birds are not managed at all, or for their populations to increase so that you can see more of them in your local area.

For each set of choices, we describe a no change option that represents the projected bird population 10 years from now if 'current management' continues. You will not have to pay any additional money via your household income tax each year for this option.

We also describe two other policies to manage pest bird species. These will cost money, so the amount of income tax you will pay as a household each year will rise.

Page 11: Example of the following choices



Displayed above is an example of the type of choice you will be presented with on the following pages.

Please consider each new page as a separate set of choices and pick the option you prefer from the three available. You will see a total of 12 different sets of choices. Results from similar surveys show that people tend to overstate how much they are actually willing to pay for wildlife management through an increase in income tax. Please bear in mind that an additional income tax payment each year will result in you having less money to spend on other things in your daily life.

Page 12: Choice 1

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Corvus splendens*

Invasive species

Projected population in Europe in 10 years time: Rare

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small increase** in population size	**Small decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	Management via **lethal control** (e.g. shooting adult birds/removal of eggs)	Management via **bird deterrents** (e.g. nets/noise machines)
£0 increase in tax cost per household per year	**£4 increase** in tax cost per household per year	**£12** increase in tax cost per household per year

No change/Policy 1/Policy 2

Page 13: Choice 2

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Columba palumbus*

Native species

Projected population in Europe in 10 years time: Abundant

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small increase** in population size	**Large decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	**No management** at all (removal of current management practices)	**No management** at all (removal of current management practices)
£0 increase in tax cost per household per year	**£2 increase** in tax cost per household per year	**£12 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 14: Choice 3

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Anser anser*

Native species

Projected population in Europe in 10 years time: Occasional

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**No change** from projected population in 10 years	**Small increase** in population size
No change from **current management** practices (bird deterrents and lethal control)	Management via **lethal control** (e.g. shooting adult birds/removal of eggs)	Management via **bird deterrents** (e.g. nets/noise machines)
£0 increase in tax cost per household per year	**£9 increase** in tax cost per household per year	**£2 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 15: Choice 4

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Branta canadensis*

Invasive species

Projected population in Europe in 10 years time: Frequent

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Large decrease** in population size	**Small increase** in population size
No change from **current management** practices (bird deterrents and lethal control)	No change from **current management** practices (bird deterrents and lethal control)	Management via **lethal control** (e.g. shooting adult birds/removal of eggs)
£0 increase in tax cost per household per year	**£9 increase** in tax cost per household per year	**£2 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 16: Choice 5

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Corvus corone*

Native species

Projected population in Europe in 10 years time: Common

High A **C** F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**No change** from projected population in 10 years	**Small decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	Management via **bird deterrents** (e.g. nets/noise machines)	No change from **current management** practices (bird deterrents and lethal control)
£0 increase in tax cost per household per year	**£0 increase** in tax cost per household per year	**£12 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 17: Choice 6

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Psittacula krameri*

Invasive species

Projected population in Europe in 10 years time: Frequent

High A C **F** O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Large decrease** in population size	**No change** from projected population in 10 years
No change from **current management** practices (bird deterrents and lethal control)	Management via **lethal control** (e.g. shooting adult birds/removal of eggs)	**No management** at all (removal of current management practices)
£0 increase in tax cost per household per year	**£4 increase** in tax cost per household per year	**£2 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 18: Choice 7

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Corvus splendens*

Invasive species

Projected population in Europe in 10 years time: Rare

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small increase** in population size	**Small decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	**No management** at all (removal of current management practices)	Management via **bird deterrents** (e.g. nets/noise machines)
£0 increase in tax cost per household per year	**£2 increase** in tax cost per household per year	**£12 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 19: Choice 8

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Branta canadensis*

Invasive species

Projected population in Europe in 10 years time: Frequent

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small increase** in population size	**Large decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	Management via **bird deterrents** (e.g. nets/noise machines)	**No management** at all (removal of current management practices)
£0 increase in tax cost per household per year	**£9 increase** in tax cost per household per year	**£4 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 20: Choice 9

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Columba palumbus*

Native species

Projected population in Europe in 10 years time: Abundant

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small decrease** in population size	**No change** from projected population in 10 years
No change from **current management** practices (bird deterrents and lethal control)	Management via **bird deterrents** (e.g. nets/noise machines)	**No management** at all (removal of current management practices)
£0 increase in tax cost per household per year	**£0 increase** in tax cost per household per year	**£9 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 21: Choice 10

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Psittacula krameri*

Invasive species

Projected population in Europe in 10 years time: Frequent

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small increase** in population size	**Large decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	Management via **bird deterrents** (e.g. nets/noise machines)	**No management** at all (removal of current management practices)
£0 increase in tax cost per household per year	**£2 increase** in tax cost per household per year	**£4 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 22: Choice 11

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Anser anser*

Native species

Projected population in Europe in 10 years time: Occasional

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**Small increase** in population size	**No change** from projected population in 10 years
No change from **current management** practices (bird deterrents and lethal control)	Management via **bird deterrents** (e.g. nets/noise machines)	Management via **lethal control** (e.g. shooting adult birds/removal of eggs)
£0 increase in tax cost per household per year	**£2 increase** in tax cost per household per year	**£9 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 23: Choice 12

Please consider this page as a separate set of choices. Which of the following options would you choose? There are no right or wrong answers

Species name: *Corvus corone*

Native species

Projected population in Europe in 10 years time: Common

High A C F O R Low

No change	Policy 1	Policy 2
No change from projected population in 10 years	**No change** from projected population in 10 years	**Small decrease** in population size
No change from **current management** practices (bird deterrents and lethal control)	**No management** at all (removal of current management practices)	Management via **bird deterrents** (e.g. nets/noise machines)
£0 increase in tax cost per household per year	**£12 increase** in tax cost per household per year	**£0 increase** in tax cost per household per year

No change/Policy 1/Policy 2

Page 24: Reason for choices In the preceding pages did you **always** choose the **No change** option?

Yes/No

As you **always** chose the **No change** option, please can you indicate your primary reason for doing so, from the statements listed below:
It was the fastest way to get through the questionnaire/I am against the management of any bird species/I am against the management of native bird species/I am against the lethal control of birds/I do not care about the management of bird species populations/I would prefer bird species management to stay as it is now/I already pay enough tax and existing public funds should pay for bird species management/The trade-off between the different options made No change the best choice for me in all sets/I do not think it is important to finance these changes in bird species management/I prefer to spend my money on other things/I could not relate to the background information provided/Bird species management should not be funded through taxation/The sets of options were difficult to relate to/The options were too expensive for what I would get out of bird species being managed/I could not afford any of the proposed option changes/Other

If you selected Other, please specify:

Page 25: Reasons for choices
When making your decision between each set of options, please indicate how often you paid attention to the various pieces of information you were provided with:

	Always	Sometimes	Never
The bird species in question			
Whether the bird species was native or invasive			
The predicted change in population size			
The type of management used to control bird impacts			
Additional income tax cost to your household per year			

Page 26: Appearance ranking

Columba palumbus · *Corvus splendens* · *Anser anser* · *Corvus corone* · *Branta canadensis* · *Psittacula krameri*

Please rank each bird species in terms of how attractive, you find their appearance, scoring from 1 (most attractive) to 6 (least attractive)

	1 (most attractive)	2	3	4	5	6 (least attractive)
Columba plumbus (native)						
Corvus splendens (invasive)						
Anser anser (native)						
Corvus corone (native)						
Branta canadensis (invasive)						
Psittacula krameri (invasive)						

Page 27: Your views on the natural world Please rate how strongly you agree or disagree with the following statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
We are approaching the limit of the number of people the Earth can support.					
Humans have the right to modify the natural environment to suit their needs.					
When humans interfere with nature it often produces disastrous consequences.					
Human ingenuity will insure that we do NOT make the Earth unlivable.					
Humans are seriously abusing the environment.					
The Earth has plenty of natural resources if we just learn how to develop them.					

Plants and animals have as much right as humans to exist.					
The balance of nature is strong enough to cope with the impacts of modern industrial nations.					

Page 28: Your views on the natural world continued Please rate how strongly you agree or disagree with the following statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Despite our special abilities, humans are still subject to the laws of nature.					
The so-called “ecological crisis” facing humankind has been greatly exaggerated.					
The Earth is like a spaceship with very limited room and resources.					
Humans were meant to rule over the rest of nature.					
The balance of nature is very delicate and easily upset.					
Humans will eventually learn enough about how nature works to be able to control it.					
If things continue on their present course, we will soon experience a major ecological catastrophe.					

Page 29: Questions about you

Finally, we are interested in knowing whether people's answers are related to their background and interests. All information you provide will be anonymous and cannot be traced back to you as an individual.

During the last five years have you been a member of, or made a donation to, any wildlife conservation or natural heritage organisations (e.g., RSPB, Wildlife Trust, National Trust)?

Yes/No

What is your gender?

Male/Female/Other/Rather not say

What is your age?

18-24 years old/25-34 years old/35-44 years old/45-54 years old/55-64 years old/65 years and over/Rather not say

What is your yearly household income (before tax)?

Under £15,000/£15,000 - £19,999/£20,000 - £29,999/£30,000 – £39,999/£40,000 – £49,999/£50,000 – £75,000/Over £75,000/Rather not say

Page 30: Thank you, please click the link below to exit the survey

Do not close your browser window. Please click on this link to exit the survey. Thank you for taking the time to complete this survey.

For questions relating to this survey, please contact Tristan Pett (-email address-).

Appendix 2. Urban greenspace users flower meadow perceptions and values questionnaire (data used in Chapters 4 and 5)

This is one of two variations of this questionnaire split between two choice experiment 'blocks'. This is choice experiment block one.

Appendix 2.1. Urban greenspace users flower meadows questionnaire

This questionnaire is part of a project run by University of Kent and University of Leeds, which aims to find out about what people think about the parks in this area.

Would you be willing to answer some questions? All answers are confidential and this should only take about 10 minutes.

1. How frequently do you come to this park (*circle*)

6 or 7 days a week	2 to 5 days a week	1 day a week	1 to 3 days a month	Less than one day a month

2. As for <u>today</u>, what are the main <u>two</u> reasons that brought you to this park?

______________________ ________________________

3. Thinking about <u>after you leave</u> this park, what <u>two</u> words would you use to describe how you feel?

______________________ ________________________

4. How long have you been in this park today?

______________________ minutes

5. How much longer do you intend to stay in this park today?

______________________ minutes

6. One of the things we are interested in is where and how far people travel to get to this park:

a. How did you travel here today? (*circle*)

Walk   Car   Public transport   Cycle

Other:__________

b. And where did you come from? (*circle*)

Home   Work   Shops   Somewhere else (where___________)

c. About how long did it take you to get here? ___________________ minutes

di. If you came from your home today, what is the street name or postcode of where you came from?

A postcode does not identify an individual property but to a group of 15 to 20 properties.

____

dii. If you did not come from your home today, what is the street or postcode of:

a. where you came from_____________ (or name of local area or landmark)

b. your home_____________

7. Now I am going to ask you about occasions in the last week when you have been out of doors.

By out of doors we mean open spaces in and around towns and cities, including parks, canals and nature areas; the coast and beaches; and the countryside including farmland, woodland, hills and rivers.

We are interested in each occasion that you have been out of doors. This could be anything from a few minutes to all day. It may include time spent close to your home or workplace, further afield or while on holiday in the UK.

However this does not include:

- routine shopping trips and commuting by car, or when you only walk/cycle along roads/streets;
- time spent in your own garden;
- time spent not in the UK

a. In the last 7 days (not including today) on how many occasions have you been out of doors?

____

b. We are interested in knowing where you have been out of doors, and also what activities you took part in while you were there.

Can you use the space below to tell us where you went (please be as specific as you can)?

For each place, select the activities that you doing while there from the list below (*The surveyor will show you a larger version*)

Name of place	Activities *(write the letters for each activity here)*
1. ____	________________________
2. ____	________________________
…	…

A. Eating or drinking out; B. Fieldsports (e.g. shooting and hunting); C. Fishing; D. Horse riding; E. Off-road cycling or mountain biking; F. Off-road driving or motorcycling; G. Picnicking; H. Playing with children; I. Road cycling; J. Running; K. Appreciating scenery (not from your car); L. Appreciating scenery from your car (e.g. at a viewpoint); M. Swimming outdoors; N. Visits to a beach, sunbathing or paddling in the sea; O. Visiting an attraction; P. Walking, not with a dog (including short walks, rambling and hill walking); Q. Walking, with a dog (including short walks, rambling and hill walking); R. Watersports; S. Wildlife watching; T. Informal games and sport (e.g. Frisbee or golf); U. Relaxing; V. Enjoying pleasant weather; W. Spending time with friends/family; X. Travelling (e.g. commuting on foot or bicycle) to work/home/shops; Y. Any other outdoor activities.

Now we are going to ask about your visit here today.

8. Please answer each of these questions in terms of the way you feel at the present moment. There are no right or wrong answers. Using the following scale please indicate, as honestly as you can, what you are presently experiencing (*circle* using scale below):

1 = Strongly disagree	4 = Neutral	7 = Strongly agree

1	2	3	4	5	6	7	Right now I'm feeling a sense of oneness with the natural world around me
1	2	3	4	5	6	7	At the moment, I'm feeling that the natural world is a community to which I belong
1	2	3	4	5	6	7	I presently recognise and appreciate the intelligence of other living organisms
1	2	3	4	5	6	7	At the present moment, I don't feel connected to nature
1	2	3	4	5	6	7	At the moment, I can imagine myself as part of the larger process of living
1	2	3	4	5	6	7	At this moment, I'm feeling a kinship with animals and plants
1	2	3	4	5	6	7	Right now, I feel as though I belong to the earth just as much as it belongs to me
1	2	3	4	5	6	7	Right now, I am feeling deeply aware of how my actions affect the natural world
1	2	3	4	5	6	7	Presently, I feel like I am part of the web of life
1	2	3	4	5	6	7	Right now, I feel that all inhabitants of earth, human and nonhuman, share a common life force
1	2	3	4	5	6	7	At the moment, I am feeling embedded within the broader natural world, like a tree in a forest

1	2	3	4	5	6	7	When I think of humans' place on earth right now, I consider them to be the most valuable species in nature
1	2	3	4	5	6	7	At this moment, I am feeling like I am only part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.

Please take a look at the area indicated by surveyor:

9. About how many <u>different species of flowering plants</u> would you say are here? (*circle*)
Note that all of them might not be in flower at the moment

Less than 5	6 to 10	11 to 20	21 to 30	More than 30

10. About how many of the <u>species of plants</u> in this area do you think are native to the UK? (*circle*)
Native species are the types of animals or plants that occur naturally in an area. Non-native species are those which don't occur naturally in an area, but have been introduced by people. E.g. Rhodedendrons and grey squirrels are both non-native species that were introduced to the UK.

No native plants	About a quarter native	About half native	About three-quarters native	All native plants

11. About how colourful would you say this area is? (*circle* using scale below)

Very few colours				Very many colours
1	2	3	4	5

12. Do you think this area provides useful resources (e.g. breeding sites, food and shelter) for pollinating insects (e.g. bees and hoverflies)? (*circle* using scale below)

Poor (not useful)				Excellent (very useful)
1	2	3	4	5

13. Please read the following text while I wait.

Parks, and the grassy areas they contain, are an important part of towns and cities. Not only do they provide a place for people to come to and spend time out of doors, but they are somewhere where wildlife (e.g. plants, insects, birds) can live.

In the UK, the government has made commitments to protect the number of species of plants and animals in the country. Grassy areas within parks may include a large variety of plant species, so could contribute to this goal if suitably managed.

In the UK, pollinating insects such as bees and hoverflies are in decline. Many wild flowers, vegetables, fruits and other crop plants depend on insect pollinators to reproduce. City parks and green spaces have the potential to support large numbers of insect pollinators if suitably managed.

Native species are animals or plants that occur naturally in an area. Non-native species are those which do not occur naturally in an area, and have been introduced by people (e.g. Japenese knotweed and grey squirrels are both non-native species that were introduced to the UK by humans). Non-native species can sometimes have negative impacts on native species, as well as impacting on people (e.g. Japanese knotweed can cost householders a considerable amount of money to remove from their property).

Planting flowers can alter the appearance of grassy areas within parks, for example by making the area more colourful.

The City Council wants to change how they manage grassy areas of similar size to this elsewhere in this park and throughout the city. There will be no loss of grassy areas suitable for playing games or picnicking as the area will be chosen carefully.

The following questions give you choices about how you might like to see the management of the grassy areas change. Choices may be paid for through an increase in council tax. You may, therefore, prefer not to see any changes, as this will not cost you anything and the management of the grassy area will remain the same.

Please now look at the photograph showing what the grassy area currently looks like *(the surveyor will show you this)*.

Photograph of what the grassy area currently looks like.

It contains 6 species of plant, half of which are native. It provides few resources for pollinating insects.

However, with additional management this could change, and the grassy area could contain either 5 or 10 additional species of plant, a quarter or three-quarters of which are native. The grassy area could also be a good or very good resource for pollinating insects.

When you turn to the following page you will be shown 6 tables of choices.

In each table, we list the qualities of the grassy area and an annual council tax cost which your household would pay over the next ten years for the management required to deliver these changes.

For each table, you have to choose one option. You cannot choose more than one option, so please pick the one that you prefer.

Option D represents the current situation where no changes occur in the grassy area and there is no additional cost to your household. You can choose Option D if you are happy with the way parks are managed at the moment or if you do not think your household can afford the extra council tax
cost. Similarly, you may prefer to see money spent on other things entirely, such as schools or hospitals.

Results from similar studies have shown that respondents tend to overestimate how much they are willing to pay. We ask you to think carefully about the different alternatives in relation to your household's income. Please note that the additional council tax payment will reduce your spending on other things in your everyday life.

There are no right or wrong answers so please provide your personal answers and choices. In some cases there may not be an option that you like - if so, choose the least worst of the combinations available.

Finally, the City Council would only implement the scheme if enough people support it.

Please now take a look at the choices shown to you by the surveyor.

Consider each table as a separate set of choice. Which of the following options would you choose for each table? There are no right or wrong answers (*Tick only one box per choice)*

Block 1	A	B	C	D
Choice 1				
Choice 2				
Choice 3				
Choice 4				
Choice 5				
Choice 6				

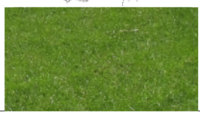
! ! ! !!!!BLOCK!1!

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS1.BL1 Choice 1	**A**	**B**	**C**	**D**
Number of plant species	An additional 5 plant species 	No change in number of plant species 	An additional 10 plant species 	No change in number of plant species 
Native species	No change: half of plant species are native	An increase to three-quarters native plant species	No change: half of plant species are native	No change: half of plant species are native
Pollinators	Medium quality for pollinating insects 	Medium quality for pollinating insects 	Medium quality for pollinating insects 	No change: low quality for pollinating insects 
Appearance				
Additional council tax cost per year to your household	£20	£60	£5	£0

Choose ONE of these and tick the relevant box on the questionnaire

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS2.BL1 Choice 2	**A**	**B**	**C**	**D**
Number of plant species	No change in number of plant species 	An additional 5 plant species 	An additional 10 plant species 	No change in number of plant species 
Native species	An increase to three-quarters native plant species	No change: half of plant species are native	A decrease to a quarter native plant species	No change: half of plant species are native
Pollinators	High quality for pollinating insects 	No change: low quality for pollinating insects 	Medium quality for pollinating insects 	No change: low quality for pollinating insects 
Appearance				
Additional council tax cost per year to your household	£60	£0	£20	£0

Choose ONE of these and tick the relevant box on the questionnaire

! ! ! !!!!!!!!!!1!

! ! ! !!!!BLOCK!1!

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS4BL1 Choice 3	A	B	C	D
Number of plant species	No change in number of plant species	An additional 5 plant species	An additional 5 plant species	No change in number of plant species
Native species	No change: half of plant species are native	A decrease to a quarter native plant species	An increase to three-quarters native plant species	No change: half of plant species are native
Pollinators	No change: low quality for pollinating insects	High quality for pollinating insects	No change: low quality for pollinating insects	No change: low quality for pollinating insects
Appearance				
Additional council tax cost per year to your household	£0	£5	£40	£0

Choose ONE of these and tick the relevant box on the questionnaire

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS5BL1 Choice 4	A	B	C	D
Number of plant species	An additional 10 plant species	No change in number of plant species	An additional 5 plant species	No change in number of plant species
Native species	A decrease to a quarter native plant species	An increase to three-quarters native plant species	A decrease to a quarter native plant species	No change: half of plant species are native
Pollinators	High quality for pollinating insects	Medium quality for pollinating insects	No change: low quality for pollinating insects	No change: low quality for pollinating insects
Appearance				
Additional council tax cost per year to your household	£20	£10	£20	£0

Choose ONE of these and tick the relevant box on the questionnaire

! ! ! !!!!!!!!!!!2!

! ! ! !!!!BLOCK!1!

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS9.BL1 Choice 5	A	B	C	D
Number of plant species	An additional 10 plant species	An additional 10 plant species	No change in number of plant species	No change in number of plant species
Native species	No change: half of plant species are native	No change: half of plant species are native	No change: half of plant species are native	No change: half of plant species are native
Pollinators	No change: low quality for pollinating insects	No change: low quality for pollinating insects	High quality for pollinating insects	No change: low quality for pollinating insects
Appearance				
Additional council tax cost per year to your household	£10	£5	£60	£0

Choose ONE of these and tick the relevant box on the questionnaire

Please consider each table as a separate set of choices. Which ONE of the following options would you choose? **There are no right or wrong answers**

CS12.BL1 Choice 6	A	B	C	D
Number of plant species	No change in number of plant species	An additional 10 plant species	No change in number of plant species	No change in number of plant species
Native species	No change: half of plant species are native	A decrease to a quarter native plant species	No change: half of plant species are native	No change: half of plant species are native
Pollinators	Medium quality for pollinating insects	High quality for pollinating insects	Medium quality for pollinating insects	No change: low quality for pollinating insects
Appearance				
Additional council tax cost per year to your household	£10	£60	£5	£0

Choose ONE of these and tick the relevant box on the questionnaire

! ! ! !!!!!!!!!!3!

14. If, in the preceding choice tables you always selected choice D (the current situation). Please indicate which, if any, of the statements listed below most closely match your reason for this choice. (*Choose one option*):

☐	Grassy areas in parks do not mean anything to me
☐	I would prefer parks to continue to be managed as they are now
☐	I already pay enough taxes and the City Council should pay for this management change
☐	The trade off between the different attributes made the “current situation” the best alternative in all choice sets
☐	I do not think it is important to finance this management change
☐	I prefer to spend my money on other things
☐	I do not think the changes in management will have an effect
☐	I could not relate to the background information
☐	The initiatives should not be funded through taxation
☐	The choices were difficult to relate to
☐	It was too expensive as compared to what I would get out of these management changes
☐	I could not afford any of the proposed initiatives
☐	Other (please specify): ____________________

These questions allow us to understand more about the responses you have given earlier in the questionnaire. We will not share this information with third parties and it will be used for academic research purposes only.

15. In the last five years have you been a member of any wildlife conservation or natural heritage organisations (e.g., RSPB, Wildlife Trust, National Trust)?

☐ Yes

☐ No

16. What is your gender?

☐ Male

☐ Female

17. How many people are with you today (not including yourself)?

____

18. How many dogs are with you today?

____

19. How many people are in your household (including yourself)?

Adults: ________________

Children (under 18): ______________

20. What is your total household income (before tax)?

- ☐ Up to £5,199
- ☐ £5,200 and up to £10,399
- ☐ £10,400 and up to £15,599
- ☐ £15,599 and up to £20,779
- ☐ £20,800 and up to £25,999
- ☐ £26,000 and up to £31,199
- ☐ £31,200 and up to £36,399
- ☐ £36,400 and up to £51,999
- ☐ £52,000 and above

21. Which of these age categories do you fall into?

- ☐ 18 – 24 yrs old
- ☐ 25 – 34 yrs old
- ☐ 35 – 44 yrs old
- ☐ 45 – 54 yrs old
- ☐ 55 – 64 yrs old
- ☐ 65 or more yrs old

22. What is your highest level of education you have completed?

- ☐ No qualifications
- ☐ 1 - 4 O Levels/CSEs/GCSEs, NVQ Level 1
- ☐ 5 + O Levels/CSEs/GCSEs, NVQ Level 2, AS Levels, Higher Diploma, Diploma Apprenticeship
- ☐ 2 + A Levels, NVQ Level 3, BTEC National
- ☐ Degree, Higher Degree, NVQ level 4-5, BTEC Higher Level, professional qualifications (e.g. teaching, nursing, accountancy)
- ☐ Other qualifications (vocational/work related, foreign qualifications or level unknown)

23. What is your current employment status?

- ☐ Employed
- ☐ Unemployed, but looking for work
- ☐ Not working (e.g. full time parent)
- ☐ Retired
- ☐ In full time education

24. Do you consider yourself to have a long-standing physical or mental health condition, impairment or disability?

- ☐ No
- ☐ Yes (please specify below)

____

25. What is your ethnic group? (*Choose one section from A to E, then tick one box to best describe your ethnic group or background)*

	A White
☐	English/Welsh/Scottish/Northern Irish/British
☐	Irish
☐	Gypsy or Irish Traveller
☐	Any other White background, *please specify below*
	________________________

	B Mixed/multiple ethnic groups
☐	White and Black Caribbean
☐	White and Black African
☐	White and Asian
☐	Any other Mixed/multiple ethnic background, *please specify below*
	________________________

	C Asian/Asian British
☐	Indian
☐	Pakistani
☐	Bangladeshi
☐	Chinese
☐	Any other Asian background, *please specify below*
	________________________

	D Black/African/Caribbean/Black British
☐	African
☐	Caribbean
☐	Any other Black/African/Caribbean background, *please specify below*
	________________________

	E Other ethnic group
☐	Arab
☐	Any other ethnic group, *please specify below*
	________________________

Thank you for completing the questionnaire.

Please note that all information is treated entirely anonymously.

Appendix 3. Publication associated with this thesis

The following co-authored paper was published during my registration as a doctoral candidate at the University of Kent and relates to the relationship between biodiversity and ecosystem services in urban areas.

Schwarz, N., Moretti, M., Bugalho, M.N., Davies, Z.G., Haase, D., Hack, J., Hof, A., Melero, Y., **Pett, T.J.** and Knapp, S., 2017. Understanding biodiversity-ecosystem service relationships in urban areas: A comprehensive literature review. *Ecosystem Services 27*, 161-171.

Appendix 3.1. Abstract

Positive relationships between biodiversity and urban ecosystem services (UES) are widely implied within both the scientific and policy literatures, along with the tacit suggestion that enhancing urban green infrastructure will automatically improve both biodiversity and UES. However, it is unclear how much published empirical evidence exists to support these assumptions. We conducted a review of studies published between 1990 and May 2017 that examined urban biodiversity ecosystem service (BES) relationships. In total, we reviewed 317 publications and found biodiversity and UES metrics mentioned 944 times. Only 228 (24%) of the 944 mentions were empirically tested. Among these, 119 (52%) demonstrated a positive BES relationship. Our review showed that taxonomic metrics were used most often as proxies for biodiversity, with very little attention given to functional biodiversity metrics. Similarly, the role of particular species, including non-natives, and specific functional traits are understudied. Finally, we found a paucity of empirical evidence underpinning urban BES relationships. As urban planners increasingly incorporate UES delivery consideration to their decision-making, researchers need to address these substantial knowledge gaps to allow potential trade-offs and synergies between biodiversity conservation and the promotion of UES to be adequately accounted for.

Full text available online
http://www.sciencedirect.com/science/article/pii/S2212041616305502

“Mary Mary quite contrary, how does your garden grow?
I live with my brat in a high-rise flat, so how in the world should I know?!”
Roald Dahl, “*Rhyme Stew*”, 1989.