The Impacts of Biodiversity and Greenspace on the Health and Wellbeing of Urban Populations

Rebecca Jane Robertson

Submitted in accordance with the requirements for the degree of Doctor of Philosophy of Biology

The University of Leeds

Faculty of Biological Sciences

School of Biology

January 2024

Contributions

The candidate confirms that the work submitted is their own and that appropriate credit has been given where reference has been made to the work of others.

Chapter 1: Led by RJR with assistance and comments provided by Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar.

Chapter 2: Led by RJR. Better Start Bradford Programme supported recruitment. Statistical analysis and preparing the manuscript were carried out by RJR with assistance and comments provided by Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar.

Chapter 3: Led by RJR. Data collection for was led by RJR, with assistance from Emma Wood, Alice Harsant, Verity Phillips, Emma Valbret, Emily Gibson, Brieannah Mollison-Read, Edward Snell, Esther Frizell-Armitage and Chao Yu. Data cleaning was led by RJR with support from Brian Kelly. The manuscript was prepared by RJR with assistance and comments provided by Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar.

Chapter 4: Led by RJR. Data collection was led by RJR, with support from Anna Cronin de Chavez, Priya McQuaid, Diana Brown, Jane Halladay, and Daniel Bingham. Data cleaning was carried out by RJR with support from Chandani Nekitsing. Statistical analysis and preparing the manuscript were led by RJR with assistance and comments provided by Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar.

Chapter 5: Led by RJR. Data collection for biodiversity and greenspace quality was led by RJR, with assistance from Emma Wood, Alice Harsant, Verity Phillips, Emma Valbret, Emily Gibson, Brieannah Mollison-Read, Edward Snell, Esther Frizell-Armitage and Chao Yu. Data cleaning was carried out by RJR with support from David Kelly. Statistical analysis and preparing the manuscript were led by RJR with assistance and comments provided by Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar.

Chapter 6: Led by RJR with assistance and comments provided by Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar. Thank you to Better Start Bradford for permitting me to use the pictures (without attribution) of the interventions associated with this thesis.

This copy has been supplied on the understanding that it is copyright material and that no quotation from the thesis may be published without proper acknowledgement.

The right of Rebecca Robertson to be identified as Author of this work has been asserted by Rebecca Robertson in accordance with the Copyright, Designs and Patents Act 1988.

©2023 The University of Leeds and Rebecca Jane Robertson

Acknowledgements

This work was supported by the Natural Environment Research Council (NERC) [NE/L002574/1] and the Better Start Bradford Programme as part of a CASE partnership. I am so grateful for all those that have helped me with my studies and PhD thesis. I could not have undertaken this journey without Christopher Hassall, Rosie McEachan, Martin Dallimer and Ian Kellar. I would like to express my deepest gratitude to Chris for the incredible support you have given me over the (many) years. You have supported me in my alternative methods and always empowered me to stretch myself (including learning R). Thank you for frequently reminding me that my health and wellbeing are important, I really appreciated this when I had to overcome health challenges affecting myself and my close family. Thank you for being an incredible role model, an inspiring teacher, a supportive supervisor and a brilliant friend. I am extremely grateful to Rosie McEachan for all your support and encouragement throughout. I loved our conversations to and from steering group and your insights into the world of public health. Thank you so much for being so proactive about creating and sharing opportunities for me to network and develop further. I want to extend a special thanks to Martin Dallimer and Ian Kellar for their support and crucial advice throughout, you have greatly shaped my studies and this thesis. It was a pleasure to work with you all.

I would like to extend my sincere thanks to colleagues from the Better Start Bradford Better Place Project, Groundwork and the Bradford Institute for Health Research. I have loved working with you all and exploring how we can make a positive impact on people and nature in the Better Start area. You were all so friendly and willing to share your specialist insights with me. Thank you for the memories we made during site visits and public engagement events. I had the pleasure of working with (in no particular order): Gill Thornton, Jenny Jowle, Adele Adams, Mark Knight, Diana Brown, Peter Murphy, Jane Halladay, Annabel Mason, Gale Maunder, Anushka Vinales, Haleema Khathoon, Daniel Bingham, Chandani Nekitsing, David Kelly, Sara Ahern and Elizabeth Caperon. With a special thanks to Anna Cronin de Chavez and Priya McQuaid for their friendship and help in establishing and implementing co-design on the ground and collecting data. You were instrumental to the project and my wellbeing throughout. Thanks should also go to the Better Star Bradford and Born in Bradford teams that supported my work, particularly by sharing opportunities for community members to be involved in my research projects.

This endeavour would not have been possible without the support, intelligence, resilience and friendship of Esther Frizell-Armitage, Chao Yu, Edward Snell, Brieannah Mollison-Read and Emily Gibson, Verity Phillips and Emma Valbret. Thank you for embracing intense fieldwork with great humour and making each season a success. A special thanks to Emma Wood, and Alice Harsant who collected data that supported the study before I even joined the project.

I would be remiss in not mentioning the kindness of the people of Bradford that let us rest in their cafés and community spaces and shared their food and favourite places with us. The people of Bradford were so generous, thank you for making us feel welcome and volunteering your time and ideas to improve your local area. I could not have done this study without your participation and feedback. Thank you to Bradford for giving me so many happy memories.

I would like to express my deepest gratitude to my husband, Dominic Sheldon, for supporting me so graciously and giving me joy, snacks and encouragement along the way. Thank you for selflessly adapting your time and offering so much love and support to enable me to reach my goals and complete this thesis. I am extremely grateful to my family. To my parents, Terence Robertson and Katrina Robertson, for their incredible examples and support throughout the journey. Thank you for your love and prayers, they kept me going. Thank you to my grandparents, siblings (and their families) and my wider family and friends for all the interest, prayers and encouragement over these years.

I am deeply indebted to my God and my saviour Jesus Christ that have given me life and the privilege to study and the opportunity to meet and work with wonderful people in a special place. I could not have completed this journey without the strength I felt from them. My prayers were answered and the Holy Ghost guided me and the law of keeping the Sabbath Day holy sustained me. I followed the teaching of not doing any work on the Sabbath day and instead focused on my faith and my Saviour. I otherwise would have burnt out many times over as there is always more that could be done but God protected me from this by giving us Sundays as a holy day. Finally, I am grateful to be a member of The Church of Jesus Christ of Latter-day Saints as my faith has offered me great comfort and strength throughout the process of writing this thesis (including regularly feeding and teaching me at the Leeds Institute of Religion on Clarendon Road).

Abstract

Urban living can be detrimental to the health and wellbeing of residents, but there is growing evidence that greenspaces and associated biodiversity can help to address some of these challenges. However, current research tends to take a simplistic approach to characterising greenspaces and tends to ignore other aspects of greenspaces such as biodiversity, user quality, social environment and perceptions of safety or attractiveness. Here, I take a multidimensional, interdisciplinary approach to the study of greenspaces, beginning with a framework for describing urban greenspaces and a suite of key measurements for greenspace studies built from the literature and in collaboration with multidisciplinary stakeholders. I then demonstrate that more detailed approaches to the characterisation of green spaces give novel insights into the relationship between greenspace and health and wellbeing. However, the traditional measure, the Normalized Difference Vegetation Index, offered similar levels of understanding. Recognising that use within parks (and, hence, the benefits accrued) is often heterogeneous, I observed people using several greenspaces and found that playgrounds were greatly used while woods were not. However, when asked, participants said they wanted to use natural features more but expressed safety concerns. To build on this, I then explore the trade-offs between attractiveness, safety, nature connection and biodiversity for key greenspace features. I identify "win-win" features (formal planting, grass, pitches, scrub, wood and wood edge) that scored well across all dimensions. Taken together, I demonstrate the strength of an interdisciplinary, place-based approach for addressing assumptions in greenspace research, building stakeholder consensus and co-designing greenspaces with communities. I show that biodiversity can play a key role either as a barrier or enabler to greenspace use and careful management can maximise benefits for both people and nature.

Contents

List of tables

List of Figures

1 Introduction

1.1 Increased risks of urban living

City living is increasing rapidly, with around 50% of the global population living in cities by 2020 (up from 25% in 1950) and that figure is predicted to increase (United Nations Human Settlements Programme, 2022). As a result, urban land cover is increasing and is the fastest-growing land use, which is “one of the most irreversible human impacts on the global biosphere” and a major threat to biodiversity (Seto et al., 2011). City environments can offer benefits to human populations such as improved access to health care, but there are also associated risks such as air pollution, the heat island effect, noise pollution, and facilitated spread of disease (Alirol et al., 2011; Rydin et al., 2012; Nieuwenhuijsen, 2016). Negative health outcomes including reduced lung function, lower birth weight, increased blood pressure and higher mortality are associated with these urban risks (Paunović et al., 2011; Laaidi et al., 2012; Pedersen et al., 2013; Nieuwenhuijsen, 2016). Urban areas have also experienced increases in non-communicable diseases such as cardiovascular disease, cancer, diabetes, and stroke, as well as mental health disorders (Beaglehole et al., 2011; Collins et al., 2011; Corbett et al., 2018). Urban areas, in particular, are also suffering from increased obesity, for example, and the majority of adults (60%) in the European Region are obese, leading to 200,000 cancer cases and 1.2 million deaths a year (World Health Organisation, 2022). The UK has the third highest rate of obesity in the Europe region (World Health Organisation, 2022). Throughout the thesis, I use the following definition of general health which “is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (World Health Organization, 2023a). When I refer to mental health and wellbeing, I use the following definition: “a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community” (World Health Organization, 2023b).

The built environment can help or hinder health and wellbeing; poor design can increase health risks while appropriate design can support active lifestyles and wellbeing (Barton and Grant, 2006; Rydin et al., 2012). Barton and Grant (2006) suggest that the built environment is a key and underpinning element of health and wellbeing in cities, that will impact the activities, local economy, community, lifestyles, and people. For example, enabling active transport through urban design can reap health benefits associated with increased physical activity (Panter et al., 2018). A simulated study found that increasing active travel (walking or cycling) for 35-50% of trips could decrease annual deaths while reducing carbon dioxide emissions (potentially improving air quality) (Rojas-Rueda et al., 2016).

1.2 Addressing risks of urban living through greenspaces

The quality of the natural environment directly affects human health and wellbeing (Millennium Ecosystem Assessment, 2005; Brauman et al., 2020). Nature's contributions to people include goods and services, material and non-material benefits and are referred to as 'ecosystem services' (Brauman et al., 2020). Urban greenspaces offer important ecosystem services to urban populations. Designed correctly, with lots of native tree species and large canopies, greenspaces can remove and store carbon and help contribute to climate change mitigation. For example, a study found that across U.S. urban areas, total tree carbon storage is estimated at 643 million tonnes (a monetary value of $50.5 billion)(Nowak et al., 2013). Urban greenspaces also contribute to decreased air pollution (Tallis et al., 2011). For example, higher residential greenness was associated with better air quality and lower personal home (indoor and outdoor) PM2.5 levels, and more time spent in their home's outdoor space (Dadvand et al., 2012). Urban greenspaces also reduce the urban heat island effect. A study in Phoenix, Arizona, found a net cooling of air (0.9 °C to 1.9 °C) and surface temperatures (0.8 °C to 8.4 °C) in vegetated areas, as well as a cooling effect that extended to areas without vegetation (Declet-Barreto et al., 2013). Urban greenspaces help urban areas adapt to changes in rainfall due to climate change. They slow runoff, increase infiltration and help reduce flooding and the transportation of pollutants (Bolund and Hunhammar, 1999; Fletcher et al., 2015). Urban greenspaces could also help manage noise pollution, for example, living closer to greenspace lowered noise sensitivity and positively impacted the perception of noise (Dzhambov and Dimitrova, 2015). The UK Forestry Commission research arm claims that planting a 30 m width of woodland could decrease noise by five to ten decibels, reducing 50% of noise received by the human ear (Forest Research, 2017).

The value of greenspace is recognised on an international level in the United Nations Sustainable Development Goals, with Target 11.7 for providing universal access to safe, inclusive, and accessible green and public spaces (United Nations, 2022). In the UK, the flagship policy of the 25-Year Environment Plan for England states that "green and blue spaces in our built environment are essential to health and happiness"(Department for Environment, Food and Rural Affairs, 2017). In recent years, local councils were encouraged by Public Health England to invest in greenspaces to promote healthier communities (Public Health England, 2020). The need for greenspace access is recognised in the UK Government's ambition that everyone should live within 15 minutes walk of a green or blue space (Department for Environment, Food & Rural Affairs, 2023). The UK Office of National Statistics adopted visits to greenspaces as an indicator of child wellbeing (Natural England, 2018). Since 2009, the UK government have also run an annual survey on access to and engagement with the natural environment (and during the coronavirus pandemic monthly surveys were carried out) demonstrating the value that the Government places on greenspaces as a public resource (Natural England, 2022).

Urban greenspaces have been specifically highlighted as public resources for health and wellbeing (Lovell et al., 2014; Dobson, 2018; Public Health England, 2020). For example, a report by a UK charity estimated the wellbeing value of frequent use of parks and greenspaces at £34.2 bn per year for the UK population and saving for the National Health Service (NHS) of £111m per year by a reduction in GP visits through greenspace visits (Fields in Trust., 2018). There is a range of mechanisms for how greenspace might provide such benefits for health and wellbeing, through indirect pathways (such as views of greenspace), incidental passive pathways (passing through on a commute) or intentional pathways such as promoting positive mental health, providing context and motivation for physical activity, or social gatherings and recreation (Ulrich, 1984; Taylor et al., 2002; Lovell et al., 2014; Lee et al., 2015; World Health Organization, 2016; Cox et al., 2018; Cronin-de-Chavez et al., 2019; Marselle et al., 2021). A review of peer-reviewed literature found 59 separate potential benefits of greenspaces, including psychological and wellbeing (i.e. decreased depression or increased happiness), cognitive (i.e. attention restoration), physiological (i.e. reduced mortality from circulatory and respiratory diseases) and the potential to reduce the incidence of infectious diseases (Sandifer et al., 2015). Greenspaces can also offer greater benefits compared to other environments, for example, those exercising outside or green walking had higher wellbeing than those indoors or urban walking (Legrand et al., 2022; Kelley et al., 2022). Benefits from greenspaces can be sustained over time and last longer than just the length of a visit to greenspace (Bakolis et al., 2018; Dobson et al., 2021; McEwan et al., 2021). For example, the mental health benefits people received from visiting areas with trees lasted up to 7 hours (Bakolis et al., 2018). Blue spaces also have positive impacts on health but are outside the scope of this study (Lovell et al., 2014; Wheeler et al., 2015; White et al., 2020; Knight et al., 2022).

Passive pathways can contribute to health by stimulating healthy microbiomes and mitigating health risks such as the heat island effect, noise pollution, flooding and poor air quality (Rook, 2010; Dadvand et al., 2012; Lovell et al., 2014; Lee et al., 2015; Marselle et al., 2021). For example, residents living closer to formal parks were more likely to achieve the physical activity recommendation and less likely to be overweight or obese (Coombes et al., 2010). However, the type of physical activity individuals engage in may not be those carried out in public greenspaces (such as gardening) (Mytton et al., 2012).

The natural environment, including greenspaces, can also offer unique and important opportunities for child development through rich and diverse sensory experiences (Beery and Jørgensen, 2018; Islam et al., 2020). Outdoor play can promote social functioning, physical health and wellbeing in children (Brussoni et al., 2015; Islam et al., 2020). Outdoor play also offers advantages over indoor play by an additional element of risk which can stimulate emotional resilience (Brussoni et al., 2015). Therefore, these key opportunities are missed for children with little contact with nature (O'Brien and Murray, 2007). In turn, childhood experience of nature plays a strong role in adulthood such as influencing the frequency and types of visits to natural places, displaying pro-environmental behaviours and connection to nature (Wells and Lekies, 2006; Thompson et al., 2008; Colléony et al., 2017). For example, Thompson et al., (2008) found that adults that were more open to visiting woodlands or green spaces alone had frequent visits to a natural place during childhood. It is also important to note that children perceive the environment differently from adults and disproportionately use informal greenspaces as play spaces (Pyle, 2002; Platt, 2012; Rupprecht and Byrne, 2014). Therefore, is it important to remove barriers and facilitate the use of greenspaces (and blue spaces) for children to maximise opportunities for development as well as health and wellbeing benefits.

It is important to recognise that greenspaces can also have negative impacts, especially poor-quality greenspaces, and these can be a risk to health and wellbeing as well as generate disservices and costs. These can include aesthetic (untidy vegetation), economic (costs of controlling species), environmental (introduction of non-native or invasive species) and health (allergies) and safety (Lyytimäki et al., 2008; Escobedo et al., 2011; von Döhren and Haase, 2015; Potgieter et al., 2017; Brindley et al., 2019; Birch et al., 2020; Cole et al., 2023).

In this study, I use the following definition of urban greenspace from Greenspace Scotland, (2021) which is 'any vegetated land or water within an urban area; this includes parks, gardens, playing fields, children's play areas, woods and other natural areas, grassed areas, cemeteries and allotments, green corridors like paths, disused railway lines, rivers and canals derelict, vacant and contaminated land which has the potential to be transformed'. Greenspaces are part of green infrastructure, (defined as 'as a network of multifunctional green and blue spaces and other natural features, urban and rural' (National Planning Policy Framework, 2021). To note this study focused on greenspace interventions for single greenspaces due to the design of funding and stakeholder engagement and co-design models. Therefore, this study uses greenspace terminology while recognising greenspaces are part of wider green infrastructure. However, there is no consensus on a definition for greenspace as there are a variety of existing interpretations and these spaces are often described as 'green' due to the vegetation (Lovell et al., 2014; Hunter and Luck, 2015; Taylor and Hochuli, 2017; Rojas-Rueda et al., 2021; Matsler et al., 2021). Greenspaces are usually managed for the public and often accessible from residential or commercial properties (Taylor and Hochuli, 2017). I use the one-word compound of greenspace throughout this study as Taylor and Hochuli (2017) suggest using this single term to simplify the literature on greenspaces. The one-word compound is preferred because it is easier to distinguish from the noun phrases (green + anything, for example, *green paper*, or space + anything which could be referring to *outer space*). This is particularly useful when conducting literature searches or systematic reviews as the term greenspace is more relevant than other studies with green or space in.

1.3 Measuring relationships between greenspace and health and wellbeing outcomes

Links between health and wellbeing and urban greenspaces are often explored by measuring one or more of the following variables: surrounding greenness, lack of surrounding greenspace, amount/area of surrounding greenspace, spatial distributions of greenspace, use (frequency and duration sometimes referred to as 'dose') and quality of surrounding greenspaces. These definitions of greenspace vary considerably in the method of measurement and the mechanisms by which they may alter health outcomes. *Greenness* (such as Normalized Difference Vegetation Index (NDVI) or land cover) was associated with positive health outcomes. These studies use spatial analysis in geographic information system (GIS) by combining spatial data with health records or self-reported health survey data with large sample sizes. Examples include the reduced likelihood of being overweight, depression in pregnant women, neuropsychological and mental health benefits for children, lower blood pressure and hypertension prevalence in women, and healthier birthweight (Dadvand, Wright, et al., 2014; McEachan et al., 2016; Klompmaker et al., 2018; Yang et al., 2019; Luque-García et al., 2022). Conversely, studies with large sample sizes using a similar method of combining GIS and health data have found that a *lack of green* is also associated with poor health outcomes such as increasing depression symptoms, lower wellbeing, higher blood pressure in women and children, risk of cholesterol and diabetes (White et al., 2013; Alcock et al., 2014; Wheeler et al., 2015; Grazuleviciene et al., 2015; Rautio et al., 2018; Plans et al., 2019; Warembourg et al., 2021). The *amount or area* of greenspace has also been shown to promote wellbeing, although effects on an individual level were small (White et al., 2013). A systematic review of 12 studies found that increasing the available greenspace can also increase health outcomes such as increasing physical activity (Hunter et al., 2015). The *spatial distribution* of greenspaces has also been linked with health outcomes. For example, an epidemiological analysis of self-reported general health in Sheffield UK (which controlled for income, air quality and age and gender) found that large greenspace patches that are well interspersed with the built environment are associated with lower levels of poor health (Mears, Brindley, Jorgensen, et al., 2019).

The *use (frequency and duration) of* greenspaces has also been associated with positive health outcomes (although bias in study designs can limit evidence quality, see the meta-analysis of 33 studies, Roberts et al., 2019). Frequency and duration of greenspace use can have a positive association with health outcomes such as self-reported health, social cohesion, physical activity and prevalence of high blood pressure as explored through cross-sectional survey based studies in Australia and the UK (Shanahan et al., 2016; Cox et al., 2018). Heo et al. (2021) found that decreased visits to urban greenspaces during the coronavirus pandemic (2020) were correlated with increased depression and anxiety in individuals in South Korea (online survey of 322 participants). Benefits could be gained through short visits (as little as 15 minutes or once a week for an average of 30 minutes or more as demonstrated by cross-sectional surveys and a meta-analysis of 33 studies (Shanahan et al., 2016; Roberts et al., 2019). However, to maximise benefits, people should use greenspace for more than 120 minutes a week (although benefits peaked around 200-300 minutes per week)(this study used data from cross-sectional survey data of 19,806 people in the UK (White et al., 2019). Although longer visits to greenspace maximise benefits, similar gains can be had by combining shorter, everyday visits to greenspace (Natural England, 2010; Rupprecht and Byrne, 2014; Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Lovell et al., 2020; Dobson et al., 2021). The benefits of spending longer in nature can be greater for those in more urbanised areas (particularly, physical activity and perceptions of social cohesion)(see cross-sectional survey data in Cox et al., 2018). Benefits of visiting greenspaces (such as physical health, social cohesion and improved physical behaviour) can be independent of the surrounding residential environment, showing that people with less access to surrounding greenspaces can have similar gains in health if they choose to frequently visit greenspaces (see cross-sectional survey data in Cox et al., 2018).

The *quality* of the greenspace may promote health and wellbeing, with poor quality reducing the use of greenspace or acting as a disservice (see survey and observational data form the following studies, Lee et al., 2015; Cronin-de-Chavez et al., 2019; Birch et al., 2020; Knobel et al., 2021). However, good quality greenspace can promote health and wellbeing (see survey and observational data from the following studies, Cronin-de-Chavez et al., 2019; Mears, Brindley, Baxter, et al., 2020; Knobel et al., 2021; Knight et al., 2022). For example, higher quality surrounding urban greenspace was associated with a higher likelihood of moderate-to-vigorous physical activity and a lower risk of being overweight/obesity, as well as increased greenspace use (this conclusion was based on combining GIS and health survey data for 2053 adults, see Knobel et al., 2021). Another element of greenspace quality is the biodiversity it supports but evidence on this emerging more recently which is sometimes neglected in greenspace studies (see the following systematic reviews Lovell et al., 2014; Lai et al., 2019; Knobel et al., 2019; Lovell et al., 2020). Lai et al. (2019) call for future research to include biodiversity, and they identify this as novel because previously there have been minor efforts to link ecological science and public health, despite the need for a multi-disciplinary approach to develop a greater understanding of the underlying mechanisms between exposure to biodiversity and health or wellbeing outcomes. Greenspace quality is an area that decision-makers can target to improve the health and wellbeing of those that use or live near urban greenspaces that offer alternative interventions to expanding or establishing urban greenspaces where land is in short supply (Knobel et al., 2019).

1.4 Improving health and wellbeing through urban greenspace biodiversity

Biodiversity is "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"(Secretariat of the Convention on Biological Diversity, 2006). Biodiversity is supported in urban ecosystems, which are unique and diverse in their own right providing a valuable habitat for a variety of species (McKinney, 2006; Nielsen et al., 2014; Baldock et al., 2015; Hill et al., 2017). Urban greenspaces (including small or informal spaces such as roadside verges, roundabouts and green roofs) can support a range of species, act as refuges and corridors for species and contribute to conservation goals (Frith and Gedge, 2000; Helden and Leather, 2004; Saarinen et al., 2005; Fuller et al., 2009; Hale et al., 2012; Nielsen et al., 2014; Hayhow et al., 2016; O'Sullivan et al., 2017). Some species excel in urban environments more compared to rural environments, for example, bumblebees, foxes, gulls, hedgehogs and peregrine falcons (Samuelson et al., 2018; Hayhow et al., 2019; Kettel et al., 2019).

There is growing evidence that this greenspace biodiversity has associations with health and wellbeing benefits (including positive attitudes and perceptions)(Fuller et al., 2007; Dallimer et al., 2012; Lovell et al., 2014; Hoyle et al., 2017; Cox et al., 2018; Public Health England, 2020; Cameron et al., 2020; Dobson et al., 2021; Methorst et al., 2021; Marselle et al., 2021). In particular birds, trees and flowers have been linked to greenspace users reporting higher wellbeing (often this data is from self-reported survey data, see the following studies, Dallimer et al., 2012; Wheeler et al., 2015; Hoyle et al., 2017; Wood et al., 2018; Southon et al., 2018; Wyles et al., 2019; Cameron et al., 2020; Methorst et al., 2021). Even perceived biodiversity has been associated with high wellbeing (see data from self-reported surveys in Fuller et al., 2007; Dallimer et al., 2012; Ode Sang et al., 2016; Southon et al., 2018). As with greenspace, a lack of biodiversity can be related to health and wellbeing outcomes. For example, Knight et al., 2022 found that living further than a 1 km walk from a high-quality public natural site (with high biodiversity) was associated with lower levels of life satisfaction in a sample of 1,606 adults in London, UK. Although, ecosystems such as estuaries that have lower biodiversity have not been shown to decrease health and wellbeing outcomes, despite the suggestion that lower biodiversity is linked to lower health outcomes (see a systematic review by Lovell et al., 2014). Therefore, further study is needed into how people receive benefits from biodiversity in urban greenspace. Note that the associations between health and biodiversity are not often studied in isolation of greenspace or the natural environment and this study focuses on urban greenspace biodiversity and recognises that greenspace and biodiversity are not explored in isolation in this thesis. The additional effect of biodiversity, if the effect of greenspace were to be controlled was not explored.

One of the greenspace biodiversity mechanisms for positive health and wellbeing outcomes involves microbial communities in cities. There is increasing research into the microbial aspect of biodiversity in greenspaces and how this can affect human-associated microbial communities relating to immune system function and allergies (Hanski et al., 2012). The relationship between greenness (including biodiversity) and allergies or inflammatory diseases is complex. However, there are theories such as the 'Old Friends Hypothesis' that link microbes to human health through our co-evolutionary history (Rook, 2010). There are theories that a decline in green and biodiversity may be linked to increases in inflammatory disease (Haahtela et al., 2013). The Microbiome Rewilding Hypothesis, suggests that natural remnant ecosystems (that often have more microbial variability compared to urban systems) can act as a source to improve microbial diversity for humans (Mhuireach et al., 2016; Mills et al., 2017). Through revegetation, the microbiome can also be restored rapidly (even in as little as 10 years) which could help promote health benefits on a shorter timetable (Gellie et al., 2017).

Reviews and experimental studies have found that skin microbiota can differ depending on people's surroundings (inside and outside) (Hanski et al., 2012; Ruokolainen et al., 2015; Lehtimäki et al., 2017; Selway et al., 2020). A study involving repeated swabbing of three individuals found changes in skin microbiota after exposure to air, soil, and leaves can occur in as little as 15 minutes to 2 hours in greenspaces (Selway et al., 2020). Greater biodiversity in immediate environments has been associated with immunity benefits (this data was from a random sample of over 100, 14 to 18 year-old school children living within a 100 × 150 km area in eastern Finland, see Hanski et al., 2012). Wojciechowska et al. (2007) found that the prevalence of allergies (asthma and allergic rhinitis) was higher in urban children (n = 201) compared to rural children (n = 203), although certain risk or lifestyle factors were similarly important contributors in both environments. This result is supported by (Kim et al., 2020, a cross-sectional study of 219,298 adults self-reporting health outcomes) that found higher surrounding greenness significantly lowered the risk of contact dermatitis and allergic rhinitis. Although these patterns may differ with local conditions (see three birth cohort studies with samples ranging from 2472 to 13,016 participants, Fuertes et al., 2014; Fuertes et al., 2016; Tischer et al., 2017). For example, greenspaces can produce pollen which can trigger allergies in those that live close by or visit (Aerts et al., 2020; Dong et al., 2021; Dzhambov et al., 2021; Zednik and Pali-Schöll, 2022). A meta-analysis (nine studies) found an increase in surrounding greenspace (10%) was associated with a significant increase (5.9-13%) in allergic symptoms; wheezing, asthma and allergic rhinitis (Parmes et al., 2020). The relationship is complex and evidence is still emerging but what is becoming clearer is that correctly designed and distributed greenspaces can be beneficial for those with allergies by stimulating immunity (Wojciechowska et al., 2007; Kim et al., 2020; Zednik and Pali-Schöll, 2022). Therefore, to minimise the negative impacts on those experiencing allergic symptoms and maximise the immune system benefits, it is important to explore the mechanisms behind greenspaces and allergies further.

A key question remains unanswered: are there particular greenspace designs or features (such as specific biodiversity) that contribute to positive health outcomes? For example, a longitudinal study of 1050 children in Portugal found that children that lived in areas with higher numbers of different plant species in surrounding greenspaces were at significantly higher risk of allergic symptoms compared to those close to fewer plant species in their greenspace (Cavaleiro Rufo et al., 2021). However, the same study found that living closer to greenspace and having a higher amount of surrounding greenspace had a protective effect on children against developing allergic diseases and asthma compared to children in neighbourhoods with smaller surrounding greenspace (Cavaleiro Rufo et al., 2021). Therefore, the features of size, distribution, and species richness of urban greenspaces can all impact health outcomes, but more evidence is needed. For example, what impact does biodiversity beyond plants have on health and wellbeing outcomes?

The above studies cover the benefits derived from contact with (or a 'dose' of) nature, which is just one side of the coin as an individual's connection to nature can further impact the benefits they receive from greenspaces (Dobson et al., 2021; Pocock et al., 2023). Richardson et al. (2021) argue that nature connectedness and turning to nature itself is a psychological need and basic component of a good life. For example, when using an app that prompted people to notice nature over seven days, participant's mental wellbeing improved and those with mental health difficulties sustained a clinically significant improvement one month later compared to their baseline (note the same benefits were experienced by participants in urban or green conditions)(Dobson et al., 2021; McEwan et al., 2021). A similar study asked university students to notice three good things in nature each day for five days and found improvements in psychological health compared to a control group (Richardson and Sheffield, 2017). Urban greenspaces can provide opportunities for "meaningful interaction with nature in close proximity to the places where people live and work" and help connect people with nature (Miller, 2005; Cox et al., 2017; White et al., 2019; Dobson et al., 2021; Richardson et al., 2021; Passmore et al., 2022; Pocock et al., 2023). Therefore, nature dose and nature connectedness should be explored simultaneously in urban greenspace studies investigating health and wellbeing outcomes. However, there is no standardized method to measure time spent in nature or nature contact and multiple definitions of nature contact (Holland et al., 2021).

Some posit that "mankind is now in an era of novel co-evolution of ecological and socioeconomic systems"(Liu et al., 2007). Urbanization is changing how humans interact with the natural environment. Some have referred to an 'extinction of experience' which is the progressive decrease in interactions between people and nature (Pyle, 1978; Miller, 2005; Gaston and Soga, 2020). For example, in the UK between 2013 and 2014, around 1.3 million children 'rarely' visited the natural environment (Natural England, 2018). One UK study found that the most common experience of nature was seeing views of nature from a window rather than being in nature, and only 32% of the population experienced being in nature (Cox et al., 2017). A recent survey of adults in England found that over a quarter (26%) had not spent any time in greenspace in the last seven days (Natural England, 2022). However, the same survey found that the coronavirus pandemic impacted how greenspaces were used as 33% of respondents reported visiting local green and natural spaces more often since coronavirus restrictions were put in place and 45% reported spending more time outdoors than before the pandemic (Natural England, 2022). This finding is not a surprise as greenspaces were a key meeting area when restrictions were placed on where and how people could meet, often being the only option. This result also complements a study in Singapore, one of the world's most densely populated cities, that found that despite increased urban living the emotional connection with nature increased (among both greenspace users and non-users) and that there were also increases in experiences with local nature (as bird species richness and abundance increased)(Oh et al., 2020). Therefore, the relationship with nature for those in urban areas is complex as opportunities for nature connection for some may decrease while increasing for others. It is important to explore who may be missing opportunities for nature connection in urban greenspaces and why, as this has implications for addressing health disparities.

1.5 Disparities in greenspace benefits

It is well documented that greenspace access and benefits are unevenly distributed (Hope et al., 2003; Dadvand, Wright, et al., 2014; McEachan et al., 2016; Rigolon, 2016; Wood et al., 2018; McEachan et al., 2018; Ferguson et al., 2018; Corley et al., 2018; Cronin-de-Chavez et al., 2019; Mears, Brindley, Maheswaran, et al., 2019; Islam et al., 2020; Burnett et al., 2021). Disparities can occur across income, usually with greater access for wealthier communities. However, this is not always the case, with some disadvantaged communities having greater access but usually to greenspaces that are of a lower quality or smaller (Mears, Brindley, Maheswaran, et al., 2019). Studies have found disparities in access to green infrastructure between ethnicities, with better access to greenspace for higher income and white households (Ferguson et al., 2018). Indeed, greenspaces in deprived areas or more racially diverse areas may have lower access, safety and aesthetic value (Corley et al., 2018). For example, a review of 49 studies found that people in lower economic classes and ethnic minorities had access to fewer acres of parks (and per person), and parks with lower quality, maintenance, and safety compared to more privileged people (Rigolon, 2016). The distribution of natural elements of greenspace can also be unequal. For example, Hope et al., (2003) found that areas that are more affluent had higher plant diversity.

The associated health benefits from greenspace can be unequal even if the access is similar. For example, proximity to greenspace was positively associated with higher birth weights for children of White British origin, but not children of other ethnicities (Dadvand et al., 2014). Yet, there were stronger associations between reduced likelihood of depressive symptoms in pregnant women and higher residential greenness for those from more disadvantaged backgrounds (McEachan et al., 2016). These findings highlight the complexity of understanding who benefits from urban greenspaces. This complexity is further supported by a study from Sheffield, UK, where people in lower socioeconomic classes received greater health benefits from surrounding greenness (Maas et al., 2009). It has also been demonstrated that green environments can help protect against income-related health inequalities, with these inequalities being lower in populations with higher residential greenness (Mitchell and Popham, 2008). There is also strong evidence that low-income, multi-ethnic communities greatly value greenspaces and recognise benefits for health and wellbeing (particularly for children) and can receive similar benefits from visits to urban greenspaces (Cronin-de-Chavez et al., 2019).

A recent UK study found that restrictions associated with the coronavirus amplified existing inequalities in greenspace uses, by reducing use by older people and females further (Burnett et al., 2021). However, they found that those from lower social grades maintained low visits to greenspace before and after restrictions (Burnett et al., 2021), whereas more affluent people that engage in employment that is easy to move online and work from home can take more advantage of greenspaces during restrictions (Honey-Rosés et al., 2021). For example, a large-scale study for England found that 37% of participants from lower income groups (earnings are less than £15,000) had not visited greenspace in the last 14 days and the pandemic did not increase visits for this group compared to other groups that engaged with nature more before and after (Natural England, 2022). Urban greenspaces can offer opportunities to address inequalities, but the picture is complex and needs further investigation into access, quality, and use of greenspaces in deprived communities. Therefore, in this study, I explore the relationship between greenspaces and health and wellbeing outcomes in a deprived area of the UK.

However, it is important to note that there are determinants beyond the physical features that influence how individuals relate to their surrounding environment. For example, satisfaction with the local area and greenspaces has been shown to impact the wellbeing of 4-year-olds, and satisfaction with local greenspace was more important than the quantity of greenspace for wellbeing (McEachan et al., 2018). Alternatively, community contexts such as low social cohesion can reduce walkability and limit visits even if greenspace is physically available and accessible, perpetuating health inequalities through differentiated greenspace access within local populations (Seaman et al., 2010). Social factors such as population density have been found to be more important than physical aspects of greenspaces in influencing visits (Lo and Jim, 2010). Cronin-de-Chavez et al. (2019) found that fear of crime, antisocial behaviour, and accidents were the overriding barriers to use, even in high-quality spaces. Individual determinants (such as care or accessibility needs) may also affect use (Cronin-de-Chavez et al., 2019). However, urban communities with higher residential greenness have been found to have a greater sense of community (Cox et al., 2018). Social context can influence the use of greenspace, Fischer et al., (2018b) found that sociocultural diversity of people and the geographical context mattered more for physical and social activities in urban parks than for nature-related activities. Perhaps nature-related activities could help to address disparities in urban greenspace use. However, there are long-standing barriers to nature-related activities for different ethnicities that need to be addressed as part of decreasing these disparities (Collier, 2019).

Understanding which green measures relate to health outcomes can help address these inequalities by targeting specific green interventions to maximise health benefits in areas with low greenspace access. For example, if access to greenspace is low, and creating or expanding existing greenspace is not possible due to the design of the built environment, then resources can be directed to address the inequalities through alternative green exposure interventions (such as street trees). For example, Marselle et al., 2020 found that a high density of street trees at 100 m around the home significantly reduced the probability of being prescribed antidepressants, particularly for individuals with low socio-economic status. Furthermore, a study in New York found that children were more physically active if they lived in areas with more street trees (Lovasi et al., 2011). For example, a study found that having 10 more trees in a city block, on average, improves health perception in ways comparable to an increase in annual personal income of $10,000 or being 7 years younger (Kardan et al., 2015).

Even smaller and informal greenspaces offer benefits for communities by providing green areas in urban environments that may otherwise be used, aesthetic value, offer play spaces for children, dog walking, gardening, shortcuts, meeting places, relaxation and conservation areas (Nordh et al., 2009; Nordh and Østby, 2013; Rupprecht and Byrne, 2014; Lovell et al., 2020; Dobson et al., 2021). Informal spaces are also disproportionately used by children, minorities, migrants and homeless people so neglecting these spaces in studies could have disproportional impacts on these groups (Rupprecht and Byrne, 2014). Informal greenspaces also offer the benefit of space without prescribed uses and allow for the creative use of space (Rupprecht and Byrne, 2014). Therefore, in this study, I explore greenspace effects on health and wellbeing in deprived communities and include greenspaces at a range of scales from small informal spaces on a street-level to neighbourhood greenspace. I aim to capture the impacts across scales, to identify if these small-scale street-level green spaces support or hinder health and wellbeing in a deprived area.

1.6 Thesis structure

In the following sections, I explain how the structure of my thesis unpacks assumptions about greenspace features and how they relate to the following research questions:

What is greenspace and how should researchers and practitioners describe it?

There is a gap in the literature regarding a standard approach to describing greenspaces in studies or projects. There are some prevailing assumptions in the greenspace literature. The first is that there is a universal understanding of what greenspace is. This is not the case with many interpretations across disciplines, cultures and contexts (Hunter and Luck, 2015; Taylor and Hochuli, 2017; Matsler et al., 2021). Very often greenspace is not defined in studies, making it difficult to collate evidence across studies and perform meta-analysis of the evidence (Taylor and Hochuli, 2017; Rojas-Rueda et al., 2021; Matsler et al., 2021). This lack of clarity can act as a barrier to leveraging funds for urban greenspaces, which are managed by local governments that are experiencing multiple pressures on a limited budget (County Councils Network, 2022). Therefore, it is important to have robust evidence on which greenspace interventions are effective. A standardised description of greenspaces included in each project would facilitate better synthesis and analysis of evidence to inform decisions and management.

In Chapter 2, I present a standard approach to describing greenspaces built by a range of stakeholders and a suite of measurements from across disciplines. This can facilitate better synthesis of disparate literature by providing a baseline of descriptions and increasing awareness of metrics across disciplines and studies. However, I do not offer a single definition of greenspace as this will vary from study to study but instead provide a standardized method for describing greenspaces to aid in collating evince from projects in similar systems. As there are various interests in urban greenspaces, there can be a plethora of metrics used in studies. The term metric is used as a way to measure elements of greenspaces such as ecosystem services, health and wellbeing or biodiversity. For example, metrics of species richness or abundance can be used to measure biodiversity (an outcome). Or the metrics of systolic, diastolic, hypertension and arterial stiffness are metrics related to measuring blood pressure. To help greenspace stakeholders identify and select metrics for their projects I built on work from a comprehensive review of reviews of health and wellbeing metrics by adding standardized measures for biodiversity and ecosystem services. I do not prescribe a standard set of metrics as metrics are chosen to suit the context of each study. Instead, I offer a suite of metrics and indicate which ones might appeal to multiple disciplines involved in greenspace projects.

What elements of greenspace have a relationship with health and wellbeing?

The current prevailing methods of exploring the links between surrounding greenspace and health rely on measuring greenness (NDVI and land cover). Research into greenspaces access and exposure often involves readily available data derived from GIS/spatial systems that measure the distance to the nearest greenspace, or the amount of greenspace in a given buffer area and excludes smaller informal greenspaces (Jarvis et al., 2020). Buffer area size varies and there is no consensus on which buffer size has the strongest link to health outcomes (Browning and Lee, 2017; Jarvis et al., 2020). However, buffer methods assume a different pattern of exposure than the exposure experienced by travelling through the built environment, which includes smaller informal greenspaces. The epidemiology literature employs buffer methodologies that offer a limited understanding of exposure to greenspace. To explore these gaps and unpack these assumptions, in Chapter 3, I compare methods of measuring greenspace using traditional buffer methods to network-based methods that explore exposure as an individual moves through the built environment. I go further by including exposure to smaller informal greenspaces.

Existing research often uses satellite-derived measures such as Normalized Difference Vegetation Index (NDVI) or land cover, therefore the scale of these measures (30-100 m) may miss important street-level differences in green exposure (Jarvis et al., 2020; Rojas-Rueda et al., 2021). Although this method distinguishes between levels of greenness, there is an underlying assumption that all greenspace is of the same quality. However, quality can influence the use of a greenspace (Lee et al., 2015; Cronin-de-Chavez et al., 2019; Birch et al., 2020). Therefore, in Chapter 3, I explore the relationship between biodiversity, user quality, street-type (trees only, trees and grass, grass only or no green present) and health and wellbeing and compare across both buffer and network-based methods.

How is greenspace used for health and wellbeing?

Epidemiological methods which are common in greenspace literature and employed in Chapter 3 offer helpful insight into the impacts of having surrounding greenspace on health and wellbeing but are limited by omitting data about an individual's use of the greenspace. Health and wellbeing benefits may not materialise if the space is not used or used for health-promoting behaviour (Lo and Jim, 2010; Mears, Brindley, Maheswaran, et al., 2019). There can be a prevailing assumption in these studies that those that use the greenspace use it the same way, for similar uses and in the whole greenspaces. Greenspaces are often considered as a single unit with little attention given to the distinct and varied areas within. Greenspace users can use some areas and not others and have a range of activities that may span multiple areas of a greenspace (from playgrounds to picnic areas). There is a need to understand the impact of the characteristics of greenspaces (including different features, quality, and biodiversity) on health outcomes and how this relates to individuals (Kruize et al., 2020; Knobel et al., 2021). Therefore, in Chapter 4, I capture who uses greenspaces, what they were using the greenspace for (including their physical activity level) and which areas of the greenspace were used. As this observation data is only a snapshot of current use, I captured individuals' views on barriers and enablers for using these greenspaces and their views on how they would like to use the greenspace.

How do people perceive different greenspace features regarding the following dimensions of experiencing features: attractiveness, safety, wellbeing, nature connection and biodiversity? Are there features that score high across all the dimensions that offer win-win opportunities?

From observational data, it was clear that only some areas of the greenspaces were used and other areas such as woods were not used. However, this data is only a snapshot of use at one point in time for that individual. The qualitative data showed there were trade-offs experienced by participants, for example, they expressed wanting more biodiversity and natural features but were concerned over safety and attractiveness of more natural features. Literature has shown that key characteristics of features in urban greenspaces can influence perceptions of urban greenspaces such as perceived naturalness, attractiveness, colour, species richness or evenness and vegetation structure, spatial layout and density (Schroeder, 1982; Schroeder and Anderson, 1984; Hands and Brown, 2002; Bjerke et al., 2006; Van den Berg and Koole, 2006; Nordh et al., 2009; Lindemann-Matthies et al., 2010; Nordh and Østby, 2013; Weber et al., 2014; McMahan et al., 2016; Hoyle et al., 2017; Fischer et al., 2018a; Harris et al., 2018; de Bell et al., 2018; Hoyle et al., 2019; Wang et al., 2019; Mouratidis, 2019). In some cases, denser and/or more diverse vegetation, trees, water and higher diversity of colour are perceived to be attractive, at times even preferred, and can enrich wellbeing (Schroeder, 1982; Schroeder and Anderson, 1984; Hands and Brown, 2002; Bjerke et al., 2006; Van den Berg and Koole, 2006; Nordh et al., 2009; Lindemann-Matthies et al., 2010; Nordh and Østby, 2013; Weber et al., 2014; McMahan et al., 2016; Hoyle et al., 2017; Fischer et al., 2018a; Harris et al., 2018; de Bell et al., 2018; Hoyle et al., 2019; Wang et al., 2019; Mouratidis, 2019). In other contexts, people show preferences for intermediate levels of vegetation and biodiversity, such as half-open areas of grass and trees (Qiu et al., 2013; Lindemann-Matthies and Matthies, 2018). It is common for people to perceive densely vegetated and low-use wood features as unsafe and associated them with antisocial behaviour (Burgess, 1995; Jorgensen et al., 2002; Bell et al., 2003; Jorgensen and Anthopoulou, 2007; Milligan and Bingley, 2007; Nisbet and Zelenski, 2013; Jansson et al., 2013; Gatersleben and Andrews, 2013; Sreetheran and van den Bosch, 2014; Mouratidis, 2019). Although, Fischer et al., 2018a, showed that people had a preference for high plant species richness in urban greenspaces (N=3716 from five European cities) and their participants consistently expressed that higher plant species richness allows for more liveable cities, offering an added value in relation to simply green spaces (with lower biodiversity). Therefore, the literature demonstrates that there is a complex relationship between greenspace features, features of higher biodiversity and perceptions or wellbeing. This complex relationship requires a multidimensional approach and rich in-depth data to understand the relationships further. Improving perceptions of more natural features can help to support biodiversity in urban areas, which can be unique and internationally important but careful management is required (Frith and Gedge, 2000; Helden and Leather, 2004; Saarinen et al., 2005; McKinney, 2006; Fuller et al., 2009; Hale et al., 2012; Lovell et al., 2014; Nielsen et al., 2014; Beninde et al., 2015; Lee et al., 2015; World Health Organization, 2016; Hayhow et al., 2016; O'Sullivan et al., 2017; Samuelson et al., 2018; Cox et al., 2018; Hayhow et al., 2019; Kettel et al., 2019; Lovell et al., 2020; Marselle et al., 2021).

Therefore, in Chapter 5 I explore perceptions of greenspace features (such as open grass, pitches, courts, wooded areas and cafes) across multiple dimensions (attractiveness, safety, wellbeing, wildness and nature connection). I use guided walks to allow participants to comment on features and take photos to gather rich qualitative data which is more detailed and realistic than sedentary methods or picture-based desk studies (Wylie, 2005; Pink, 2007; Scott et al., 2009; Middleton, 2010; Evans and Jones, 2011; Macpherson, 2016; Middleton, 2018). I also suggest ways to balance these trade-offs through management and design. Finding broad consensus for features and ways to improve perceptions of more natural features is key as greenspaces hold multiple roles in the urban environment and local communities and there are often limited resources (usually sourced from public money) to design and maintain greenspaces to fulfil these multiple purposes (Ode Sang et al., 2016; O'Sullivan et al., 2017).

How does actively thinking about greenspace features while walking through a greenspace influence perceptions of that greenspace?

Literature has shown that exposure to greenspace for as little as 15 minutes can have a positive impact on wellbeing (Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Roberts et al., 2019; Dobson et al., 2021). From Chapter 2 the wellbeing impacts of greenspaces are important across stakeholders and from Chapter 4 participants said they'd like to use natural features more for their wellbeing. Therefore, in Chapter 5, I explore the impact of a walk in the greenspace on perceptions of the greenspace features and wellbeing. Previously, nature connection was found to be a key influence on the wellbeing received from spending time in the natural environment (Dobson et al., 2021; Richardson et al., 2021; Pocock et al., 2023). Therefore, I also recorded the impact of the guided walk on nature connection and perceived species richness.

1.7 The study system: using longitudinal health data and multi-disciplinary methods to understand biodiversity and greenspace impacts

Study setting

This study took place in Bradford, a large urban city located in the north of England, United Kingdom, with a population of over 500,000 people (2021 census, Bradford Metropolitan District Council, 2022a)(Figure 1.1). Bradford is a historic city that grew out of the industrial revolution and was influenced by manufacturing with high inner-city housing density (similar to other northern UK cities such as Sheffield, (Mears, Brindley, Jorgensen, et al., 2019)). Bradford has high levels of ill health, with a higher than UK average prevalence of obesity (adult and child), diabetes, mental health disorders (such as depression), incidence of wheezing disorders amongst children and lower birth weight in babies (Bradford Metropolitan District Council, 2016; Mebrahtu et al., 2016; Office for Health Improvement and Disparities, OHID, 2021). I specifically focused on three electoral areas (known as wards, Little Horton, Bowling and Barkerend, and Bradford Moor) which are within the 10% most deprived wards in England (IMD, 2019) and ranked as wards with the 2nd, 3rd and 4th highest deprivation within the 30 districts of Bradford. These are part of well-established and long-running birth cohort studies and were the focus of the Better Start Bradford: Better Place Project that would be making changes to urban greenspaces in these wards to promote positive health and wellbeing outcomes for children under the age of 4 years old. One purpose of this thesis was to establish baseline data and then evaluate the impact of the changes associated with the Better Place Project in the greenspaces across these three wards. The thesis focuses on biodiversity and the health and wellbeing of the local community members (particularly focusing on under-4-year-olds) in the Better Start Bradford area.

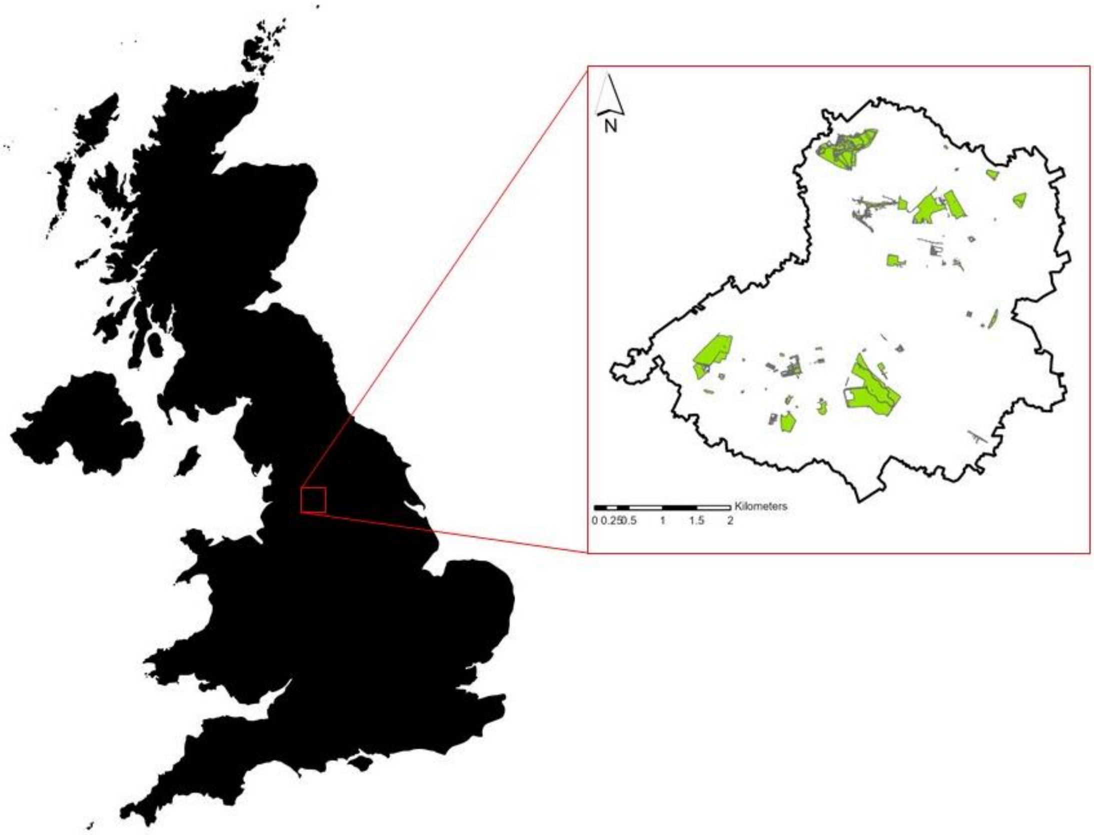


Figure 1.1 Map of the study area, part of Bradford in the United Kingdom and the greenspaces in the study area. Contains OS data © Crown Copyright OS Open Green Space (2023).

Study population: including infants in greenspace research

There is limited literature on urban greenspaces and early childhood development, health and wellbeing, a recent systematic review found benefits for perinatal health, physical health, psychological health and respiratory health (Lai et al., 2019; Islam et al., 2020; Rojas-Rueda et al., 2021). For example, greater childhood exposure to green was associated with increased levels of physical activity and a lower risk of obesity and neurodevelopmental issues, while a lack of green had negative impacts such as an increased risk of preterm birth (Grazuleviciene et al., 2015; Islam et al., 2020). However, the benefits were not equally distributed across ages, genders and socioeconomic groups (Islam et al., 2020). There could also be negative impacts such as higher surrounding greenness associated with more pollen led to increased asthmatic symptoms in children (Islam et al., 2020). The review found 23 relevant papers and these papers relied on 'greenness' as a measure of exposure (which neglects the variation across greenspaces in quality or biodiversity). However, it is clear that biodiversity can have positive impacts on health and wellbeing in adult populations, therefore this relationship should be explored for the infant populations (Fuller et al., 2007; Dallimer et al., 2012; Lovell et al., 2014; Hoyle et al., 2017; Cox et al., 2018; Public Health England, 2020; Cameron et al., 2020; Rojas-Rueda et al., 2021; Dobson et al., 2021; Methorst et al., 2021; Marselle et al., 2021).

A focus on early life in this study offers a unique opportunity to follow the impacts of interventions from the beginning and measure if there are sustained impacts or behaviours throughout someone's life. The early years are also key to developing physically, emotionally and cognitively and for forming health-promoting habits (World Health Organization, 2008; Marmot et al., 2010). In a seminal review in the UK of health inequalities, it was recommended that addressing inequalities in early years was a priority for reducing health inequalities across the country (Marmot et al., 2010). In a follow-up report, 10 years after they found that disparities persisted or had got worse (such as shorter life expectancy in deprived areas, increased childhood poverty and for some age group mortality rates increased). In fact, one analysis predicted a national cost of £16.6 billion due to late intervention for children and young people that could have been prevented if targeted at early life stages (Early Intervention Foundation, 2016). In summary, intervention in early life can have lifelong impacts, it is the stage where disparities are disrupted most effectively and interventions at this life stage are cost-effective and offer significant returns on investment (Marmot et al., 2020). Experiencing connections with nature in childhood plays a strong role in adulthood such as influencing the frequency and types of visits to natural places, displaying pro-environmental behaviours and connection to nature (Wells and Lekies, 2006; Thompson et al., 2008; Colléony et al., 2017).

In this thesis, I build on the wealth of data and research exploring urban greenspaces and health and wellbeing in the Bradford area (Dadvand, Wright, et al., 2014; McEachan et al., 2016; Wood et al., 2018; McEachan et al., 2018; Ferguson et al., 2018; Cronin-de-Chavez et al., 2019). Previous research in the Bradford area demonstrates that there is an opportunity to increase health and wellbeing outcomes for communities with high deprivation through improving urban greenspaces, particularly with biodiversity-based interventions. For example, McEachan et al. (2016) and Cronin-de-Chavez et al (2019) found that people in the area greatly value urban greenspaces and that there was a stronger association between higher residential greenness for those from more disadvantaged backgrounds. Wood et al. (2018) found that biodiversity in Bradford parks had a strong association with wellbeing and these benefits were experienced equally across age, gender, and ethnic background. Therefore, in this thesis, I explore the impacts of urban greenspace and biodiversity on health and wellbeing in early life, as well as for adults.

I aim to address a gap in greenspace literature by taking into account biodiversity in relation to public health and specific influences in the early years (Rupprecht and Byrne, 2014; Lai et al., 2019; Rojas-Rueda et al., 2021). When studies explore this relationship they are often cross-sectional in design and do not make use of epidemiological data (Lai et al., 2019; Rojas-Rueda et al., 2021). Lai et al. (2019, p. 388) go further by suggesting that 'a joint public health–ecology–bioinformatics program of work could provide robust, evidence-based solutions for improving the quality of urban greening policies worldwide, a win–win strategy for both humans and nature'. Especially as positive biodiversity and conservation outcomes are not always part of green infrastructure policy or projects so the win-win opportunities are often overlooked (Mu and Li, 2020). Therefore, in this thesis, I begin to address some of these gaps and unpack some of the prevailing assumptions in the urban greenspace literature. I build on literature by exploring the relationship between health or wellbeing and biodiversity by using data from a unique and large birth cohort data set (which I describe below) and expand on the existing biodiversity knowledge for well-documented urban greenspaces in the study area. My work also takes place in a deprived area, so my results have relevance for addressing health disparities through managing publicly accessible urban greenspaces and their associated biodiversity. The focus on early years also offers insight into ways to promote long-lasting healthy (and potentially nature-based) habits in greenspaces from a young age.

Birth cohort studies associated with this thesis

The health and wellbeing data used in this study are from birth cohort studies located in the study area (Wright et al., 2013; Dickerson et al., 2016; Dickerson et al., 2022). Birth cohort studies offer longitudinal health data for the participants. These offer some advantages over the gold standard approach of replicated randomised control trials (RCTs) as these trials are expensive, can take a long time to set up and are single-intervention focused (Dickerson et al., 2016). Whereas birth cohorts can offer robust evidence even when effects are small or take longer to emerge by frequently collecting evidence which is relevant to local and social contexts and care settings (Craig et al., 2012; Wright et al., 2013; Dickerson et al., 2016). Often these studies rely on observations but with the correct design, can gather evidence on multiple interventions and have a control group. In this study, this design is referred to as an experimental birth cohort study and it is thought to be one of the first cohort studies of its kind (Dickerson et al., 2016). In practice, the physical interventions associated with environmental changes (such as new play equipment in greenspaces) will be applied in an intervention area and compared to a control area of Bradford, and for behavioural or educational interventions, a control and intervention group will be recruited for comparison.

I use birth cohort data from the Born in Bradford (BiB) family cohort which includes more than 13,500 babies (recruited between 2007 and 2011) (Wright et al., 2013). Although the Born in Bradford (BiB) cohort has 13,500 babies across Bradford, I only include a sub-sample of these (5240) in the analysis by excluding those that are outside of the three wards of interest. The participants for the Born in Bradford (BiB) cohort were recruited by asking mothers that were booked to give birth in the city's primary maternity unit through a baseline survey. Participants were also able to give consent for long-term follow-up for themselves and their child (including routine data links)(Wright et al., 2013). The second birth cohort data included in this study is the Born in Bradford's Better Start (BiBBS) cohort (Dickerson et al., 2016; Dickerson et al., 2022). The BiBBS data set includes 2644 mothers recruited between January 2016 and March 2020 that lived within the three Bradford wards of focus (Little Horton, Bowling and Barkerend, and Bradford Moor). Data is collected from a baseline survey from the mother and partners during pregnancy and then routine health data is linked throughout the child's life (Dickerson et al., 2016; Dickerson et al., 2022). The questionnaire collects data on social, economic, environmental, health and wellbeing factors through validated and recognized survey questions (Dickerson et al., 2016; Dickerson et al., 2022). Physical samples were also taken from the mother (blood, urine, and a biomarker) and both parents are given the opportunity to give a saliva sample (which also acts as a biomarker). Parents can also give consent for similar samples to be taken from the children throughout their lives. The participant's involvement with any of the 22 interventions (including greenspace interventions) in the programme is also recorded alongside follow-up surveys on health and wellbeing (Dickerson et al., 2016; Dickerson et al., 2022). The BiBBS cohort is ongoing and still recruiting.

Study design: applying an interdisciplinary, mixed-methods and place-based approach to greenspace research

This study is place-based as I involved a range of stakeholders from the community and applied various methods to understand better a specific place, the greenspaces and the community context. As urban greenspaces are a socio-ecological construct, studying these spaces requires a range of methods (Mcintyre et al., 2000; Rupprecht and Byrne, 2014; Hunter and Luck, 2015). For example, a systematic review of greenspace studies identified a reliance on particular methods in greenspace research, where studies were dominated by user surveys (Rupprecht and Byrne, 2014). Rupprecht and Byrne (2014) suggest photography based-methods (especially where participants are the photographer), ethnographic methods such as observations and technology-based methods that use GIS and interactive elements can expand on learning from user surveys.

Therefore, in this study, I applied a range of methods, including many of those suggested and address research questions with mixed methods and aimed to involve community members as early as possible. In Chapter 2, I combined methods of a literature review with survey methods to capture the preferences of stakeholders from multiple disciplines (and who themselves are part of the community) and highlight consensus around descriptors and metrics for urban greenspace projects. In Chapter 3, I use methods familiar to public health professionals and city planners to explore associations between greenspace access and exposure, and health and wellbeing outcomes. The data for this chapter is from a longitudinal birth cohort study, which is a recognised method in the field of epidemiology. In Chapter 4, I use a recognised tool from health sciences to record observed behaviour and physical activity in urban greenspaces. To understand these observed patterns further I used a photo-voice method and analysis familiar to social scientists. In Chapter 5, I expand on the photo-voice methods to combine them with guided walks and use a multi-dimensional approach to explore trade-offs surrounding biodiversity and attractiveness and safety. Finally, to generate the underpinning data for this thesis on urban greenspaces I used tools from planning (to map greenspace distribution, gaps in provision and access points), social science (photo-voice methods and a tool to assess user quality of greenspaces) and ecological methods to capture the biodiversity, such as species abundance and richness and number of habitats.

Therefore, in this thesis, I demonstrate the strength of an interdisciplinary, mixed-methods and place-based approach for unpacking prevailing assumptions in greenspace research, to identify consensus from multiple stakeholders, facilitate the co-design of urban greenspace interventions, and understand community use, perception of and aspirations for greenspaces. As well as how this links to the impact of greenspace access, quality (including biodiversity) on health and wellbeing outcomes. I also begin to address an identified gap in the literature by uniting biological science and public health, to explore the impacts of biodiversity and greenspace quality on health and wellbeing (Lai et al., 2019; Knobel et al., 2019; Mu and Li, 2020; Rojas-Rueda et al., 2021).

Co-design in greenspace research in the Better Start Bradford: Better Place Project (associated with this thesis)

There is a growing body of literature that suggests 'co-production' of knowledge can integrate values into the research process and increase the uptake of research (Young et al., 2014). Co-design can reduce social distance, knowledge, power imbalances between different participants, and promotes a fairness in the process of information production (Lemos and Morehouse, 2005; Filipe et al., 2017). It should continue to be "a dynamic, experimental, and reflective process sustained by different forms of engagement, interactions, and social relations" (Filipe et al., 2017, p. 5). The benefits of co-production include uncovering unanticipated findings, insights and priorities through including a range of perspectives and can promote a range of outputs from traditional research such as reports and articles to new relationships, community solidarity, new products and new methods. Frantzeskaki (2019) offer case study examples of how co-designing greenspaces led to a spill over effect of extended participation in co-creation and co-management in urban greenspaces with those communities initially engaged.

Indeed, the World Health Organisation recommend that greenspace interventions be co-designed with stakeholders to aid implementation, increase the success of interventions (as well as extend the longevity of any positive impacts) and ensure that benefits are experienced by the local community (World Health Organization, 2017). The European Landscape Convention, encourages the aspirations of local people for landscape features and landscapes to be integrated into the management and design of landscapes to facilitate stewardship and promote multiple benefits for the environment and people (The Council of Europe, 2004). When co-designed and implemented effectively with representative community engagement and interdisciplinary methods, nature-based interventions in greenspaces can offer win-win opportunities for ecology, environment, society and re-development or advancement of an area (Frantzeskaki, 2019). Green-spaces that are co-designed can increase acceptance, subsequent use, multi-functionality of an area and sense of belonging, ownership, stewardship and generate a new greenspace commons with collaborative governance involving multiple communities with diverse backgrounds (Frantzeskaki, 2019). For example, a review of built environment interventions aiming to increase green space use found that out of 120 spaces with co-designed interventions, 109 experienced increases in use and for those without co-design saw a decrease in post-intervention use in the spaces (7 of 16 spaces)(Roberts et al., 2018). However, considerations of the resources, time and expertise available for co-production should be taken, as the process has been described as 'difficult and ambitious'

(Sutherland et al., 2017). Oliver et al. (2019) detail the challenges and costs associated with co-design, such as creating conflict, consuming resources, and lead to misunderstandings.

Therefore, as part of the interdisciplinary, mixed-methods and place-based approach, the Better Start Bradford: Better Place Project, which is associated with this thesis, used co-design methods to involve a range of stakeholders and community members in the co-design of the greenspace interventions in the study area. Stakeholders of the project had a joint understanding of co-design, that it was an iterative process that begins in the early stages of a project in order to define the issues and to formulate questions and solutions together (Latour, 1998; Young et al., 2014). As a researcher, I was involved with co-design by collecting and communicating data from stakeholders on how greenspaces are used, aspirations for greenspace use/features and perceptions towards specific greenspace features. The data from this thesis that was collected through participatory methods informed greenspace intervention designs (some examples are discussed in 6.3 Implications for greenspace design and management). The evaluation of the co-design process was outside of the scope of this thesis. However, references to the co-design process are shared when relevant to each chapter.

2 What should be measured in urban greenspace projects and research? A multi-disciplinary suite of descriptors and metrics agreed by greenspace stakeholders.

2.1 Abstract

There is considerable literature on the wide-ranging benefits of urban greenspaces. A strong evidence base for the effectiveness of greenspace interventions could help to direct limited resources to maximise benefits. However, the collation and synthesis of evidence is constrained by disparate literature spread across multiple disciplines with different definitions of greenspace which in turn generates a plethora of greenspace metrics complicating the evidence landscape further. Raising awareness across disciplines of definitions and metrics used could help to harmonize terminology and evaluation of urban greenspace projects and aid in evidence synthesis. Here, using a survey with 26 descriptors (elements of greenspace definitions) and 190 metrics I asked a range of stakeholders (n=10, comprising academics, community member, community workers, delivery partners and local government) to identify a baseline list of descriptors and metrics that should be reported in greenspace projects. Participants scored each descriptor and metric according to how important they considered its measurement. I identify the metrics with high priority and agreement across stakeholders and which metrics are used by the range of stakeholders. Participants recognise that urban greenspaces offer both benefits and costs, suggesting that these should be considered together in projects. I highlight the interdisciplinary nature of urban greenspace research as descriptors and metrics with high priority across stakeholders were from ecology and social science. Based on these findings, I recommend a set of descriptors to standardise the reporting on characteristics of urban greenspaces to aid evidence synthesis. I also highlight metrics that have a consensus across multiple stakeholders. Future studies can use this list of metrics as a tool for research design to identify diverse metrics, report metrics that are relevant across stakeholders and disciplines, and prioritise those metrics that might have particular relevance to local situations. The results are mapped onto definitions from a search of the literature to add context and highlight where studies could go further than the standardized descriptor list I present.

2.2 Introduction

Urban greenspaces can provide benefits for people and nature (Lovell et al., 2014; Díaz, et al., 2018; Marselle et al., 2021). As the number of people living in urban areas grows, there has been an associated growth in research exploring how to maximise these benefits. As urban environments are physical and social entities, studies are often multi- or interdisciplinary, combining elements from natural and social sciences, and can encompass a range of stakeholders and multiple research clusters (Mcintyre et al., 2000; Hunter and Luck, 2015; Mu and Li, 2020).

In a UK context, the maintenance and costs of public urban greenspaces are the responsibility of the local authorities. Local councils were encouraged by Public Health England to invest in greenspaces to promote healthier communities (Public Health England, 2020). A survey in England found that urban greenspaces (including gardens) are the most commonly used space (Natural England, 2022). For example, the same survey recorded high use among adults, with the majority (63%) visiting a green and natural space in the previous 14 days when they were surveyed and a total of 299,828,943 visits to green and natural environments in March 2022 alone (Natural England, 2022). However, there have been substantial cuts in local government funding, with one review finding a loss of 16% in spending power between 2010 and 2020 driven by a reduction in central government grants (Institute for Government, 2020). Inflation is leading to increased costs for local authorities to provide key public services. A report from the County Councils Network found that 40 of England's largest county and unitary authorities are predicted to have additional costs of £3.5bn for 2023-2024 due to inflation (County Councils Network, 2022). Therefore, it is important to identify how to use the restricted public money effectively to maximise benefits for people and nature using robust evidence. To make the case for investment in public urban greenspaces it is important to understand how they impact health and what types of features are most impactful. However, the multidisciplinary nature of greenspace research has led to a diverse literature that is difficult to synthesise, thereby complicating the measurement of the effectiveness of interventions (Taylor and Hochuli, 2017; Rojas-Rueda et al., 2021; Matsler et al., 2021). A recent systematic review found that, due to the variation in greenspace definitions, it was impossible to perform a quantitative summary of studies. Even in studies with similar definitions of greenspaces, the quality or accessibility was not defined or reported (Rojas-Rueda et al., 2021). A recent survey of local authorities in Poland found that there were multiple interpretations of urban greenspace often leading to a bias towards particular types being included (such as parks) and others (such as informal greenspaces) excluded from planning policy or decisions, resulting in a focus on a fraction of available greenspace and neglecting the contribution of all greenspaces to green infrastructure, biodiversity and ecosystem services (Feltynowski, 2023).

A review of 125 greenspace journal articles (2009-2014) found that less than half of them (n= 56) defined "greenspace" in the context of their study (Taylor and Hochuli, 2017). Of the studies with definitions, these definitions varied widely, including a) diversity of greenspace types considered together as greenspaces in the broadest sense (for example, tree-lined streets to playing fields), b) definitions of greenspaces using examples rather than characteristics (such as open land), c) definitions based on ecosystem services (such as growing food), d) definitions based on land use (such as undeveloped land) and e) general vegetated areas without further detail. The language can be ambiguous in these definitions, for example, street trees and green infrastructure could be the same or different, or saying 'parks and greenspaces' can confuse readers further as parks are greenspaces (Taylor and Hochuli, 2017). Even within the same discipline, there can be multiple meanings. For example, Taylor and Hochuli (2017) highlight two papers in the journal 'Policy and Health' that define greenspaces differently: a) natural environments, including parks, woods, gardens and coastal areas compared to b) normalized differentiation vegetation index (NDVI). The reference to greenspaces in multidisciplinary journals amplifies this further. The same issues are associated with the term green infrastructure (which includes greenspaces), the term was ambiguous, few studies defined them and different disciplines (ranging from urban planning, urban forestry, ecology, engineering, landscape architecture, and law) had divergent concepts of green infrastructure (Taylor and Hochuli, 2017; Rojas-Rueda et al., 2021; Matsler et al., 2021). Although some studies refer to the EU definition and strategy of green infrastructure, it is not used in all studies and comparisons are still difficult (Mu and Li, 2020). The same ambiguity and divergent concepts were found in grey literature in the top 20 hits on Google for green infrastructure (Matsler et al., 2021). There was some emerging consensus (102 of 125 papers) that greenspace refers to greenspace within urban environments (Taylor and Hochuli, 2017) and that it is often land that is not built on (Mu and Li, 2020). Although the term urban has similar ambiguity and should be defined more clearly in each study (Mcintyre et al., 2000).

Taylor and Hochuli, 2017 also found that greenspace quality had multiple interpretations and was subjective (often biased towards the author's discipline). Greenspace quality is often equated with greenspace size but there are additional aspects of quality that should be explored (such as access, safety, social context and inclusion, aesthetics and biodiversity)

(Corley et al., 2018). A review found that multiple definitions of greenspace and a lack of recognised or standard characteristics of greenspace that are to be associated with health outcomes mean that very few studies include quality, instead focusing on greenspace quantity and health (Lai et al., 2019). A review of tools for assessing greenspace quality found that none of the tools assessed included a definition of greenspace and coupled with the lack of available data for some tools it is difficult to replicate the methods for measuring greenspace quality, making evidence synthesis across studies more difficult (Knobel et al., 2019).

Although ambiguity can be beneficial by encouraging interdisciplinary work through its broad application and generating a high diversity of research outputs, the ambiguity can also lead to 'greenwashing' and misunderstandings or result in low public opinion if there is a lack of delivery for genuine multi-functionality of greenspaces (Mu and Li, 2020; Matsler et al., 2021). This ambiguity in greenspace terms can act as a barrier to synthesising evidence on greenspace, particularly inhibiting meta-analysis of greenspace interventions, creating a barrier to the delivery of benefits that people and nature could be receiving from greenspaces. The ambiguity in definitions of greenspace and green infrastructure has implications for biodiversity as it can group ecosystems, habitats and land use types under one umbrella of greenspace where in reality the biodiversity in these spaces differs and requires specific management (Mu and Li, 2020). Although, it should also be recognised that biodiversity itself can be interpreted and measured in different ways by various disciplines in greenspace studies (Lovell et al., 2014). Researchers are still determining if there is a difference between ecosystem services derived from the number of species (species richness) or the number of individuals of a species (species abundance). When linking greenspaces to health there are similar challenges in studies defining health outcomes. For example, a review of greenspace studies also found that there was also variation in definitions of health outcomes and metrics, not defined or didn't use the International Classification of Disease code (ICD) of the health outcome (Rojas-Rueda et al., 2021). Therefore, a standardized approach for describing and reporting on greenspaces, biodiversity, ecosystem services and health and wellbeing in urban greenspace studies would benefit collation and meta-analysis of evidence.

In the field of medicine, a "core outcome set" is created to help standardise measures and reporting across studies and aid in evidence synthesis and meta-analysis on particular health topics. These are defined as 'an agreed standardized collection of outcomes … which should be measured and reported in all trials for a specific clinical area' (Williamson et al., 2012). The outcome sets are built from consensus across key stakeholders such as patients, carers and health care professionals (Williamson et al., 2012). In this way, the core outcome set will include a range of outcomes that capture multiple perspectives and experiences of a system. Similar standardisation exercises have occurred such as the International Physical Activity Questionnaire (IPAQ) which offers a tool for self-reported physical activity (Craig et al., 2003). I explore what a core outcome set could look like for describing and reporting on urban greenspaces projects by asking diverse stakeholders from the same urban greenspace project. However, due to the complex and multidimensional elements of urban greenspaces, and that those elements can also vary across time, it is not appropriate to have a single definition of greenspace or core-outcome set of metrics cannot be applied across all contexts (Mcintyre et al., 2000; Hunter and Luck, 2015; Taylor and Hochuli, 2017).

Therefore, Taylor and Hochuli (2017) and Matsler et al. (2021) recommend that researchers should define what greenspace or green infrastructure means in their study and place it in the context of meaning across disciplines and cultures. This definition should integrate both qualitative and quantitative aspects of greenspaces. These clear definitions should aid comparisons across multiple disciplines. A common approach such as a core outcome set or checklist for describing greenspaces would help comparisons and collation across studies and disciplines.

In this study, I wanted to understand the different definitions of greenspace within a multidisciplinary team working with the same greenspaces. I aimed to identify the common ground across the stakeholders (including academics, local government, delivery partners, community workers and community members) from which to prioritise elements of greenspaces that should be described in every project. I use the term *descriptors* for the items participants ranked in terms of defining a greenspace as these would be used to describe characteristics of the urban greenspace. As greenspace studies are interdisciplinary, I also wanted to highlight consensus on the metrics prioritised by a range of stakeholders. I use the term *metrics* in this study for the items ranked for measuring elements of greenspaces such as ecosystem services, health and wellbeing or biodiversity. Metrics can be used to measure outcomes such as biodiversity (*outcome*) and species richness and abundance would be two *metrics*. Another example would be blood pressure as a health outcome with four metrics: systolic BP, diastolic BP, hypertension and arterial stiffness. The stakeholders would then rank the outcomes and associated metrics. In this way, a prioritised 'suite' of metrics grouped by outcomes could provide a starting point for other studies as they can identify metrics that are high priority and used in other projects.

I also recorded which were the most used definitions and metrics by the stakeholders in their greenspace projects to identify if there was a gap between those descriptors and metrics that are seen as important and those that are used on the ground. The aim was to have an accessible list of descriptors for greenspace project stakeholders to use, particularly practitioners that may be responsible for reporting on greenspace projects to funding bodies in grey literature. Greenspace project refers to projects or studies relating to observing, using, changing or measuring greenspace *and* is reporting on the project in peer-review or grey literature. Examples include, an informal community groups evaluating an organised greenspace activity, practitioners evaluating the impact of an intervention or a formalised research study intended for peer-review. The aim is that greenspace projects at all scales could explore reporting the basic set of descriptors of the greenspaces involved so that evidence can be synthesised across studies and even small projects can be included. The aim is *not* to have a standard definition of what a greenspace is but to have a standard *approach* to describing greenspaces when reporting. In this way, a basic set of descriptions (including aspects like size, type, management, and ownership of greenspace) could be compared for the greenspaces used within and across projects.

I included a range of metrics covering the 14 dimensions from Hunter and Luck (2015): access, ecosystem services (disservices and costs), area, vegetative areas, land use and vegetation descriptions, and socio-cultural aspects. Alongside biological metrics, I also included metrics relating to health and wellbeing as this is often the context within which urban greenspace projects are conducted. The 'suite' of metrics aims to collate and simplify the vast and disparate literature in an accessible format for the range of stakeholders involved with greenspace projects (at a range of sizes) so they can be aware of existing metrics and where these metrics have been applied previously. This could lead to future projects using metrics that have been applied before in peer-reviewed literature making evidence synthesis easier and potentially reducing effort by providing a comprehensive source of metrics that are ready to use and no need to generate a new measure. However, projects can add to or generate new metrics and methods if they do not exist already.

2.3 Methods and analysis

Greenspace descriptions and metrics

I began with a comprehensive list of greenspace metrics drawn from a multidisciplinary literature covering ecology through to urban planning (Mcintyre et al., 2000; Hunter and Luck, 2015; Taylor and Hochuli, 2017; Rojas-Rueda et al., 2021). I aimed to make the long-list as comprehensive as possible and to include multiple disciplines and include both ecosystem services (benefits to people) and disservices or costs that could be associated with urban greenspaces. I used the Common International Classification of Ecosystem Services (CICES, V5.1) (Haines-Young and Potschin, 2018) to list possible ecosystem services including provisioning (abiotic and biotic), regulation & maintenance, the transformation of biochemical or physical inputs to ecosystems, and cultural (abiotic and biotic). For capturing the disservices or costs of greenspaces these included aesthetic issues, economic issues, environmental issues, health and safety issues or unintended consequences, issues in use, and mobility issues adapted from (Lyytimäki and Faehnle, 2009; Escobedo et al., 2011; von Döhren and Haase, 2015; Potgieter et al., 2017). For biodiversity-specific metrics, I used the Essential Biodiversity Variables which offer a list of metrics to evaluate key aspects of biodiversity (such as species, ecosystem composition, habitats, genetics, survival rates, and traits like phenology) particularly as they are sensitive to change (Pereira et al., 2013). The aim was to explore if all or some of these descriptors or metrics had consensus around priority from multiple stakeholders and therefore could be readily applied to multidisciplinary greenspace projects. Although these frameworks exist, not all stakeholder groups are aware of them and not all aspects of the existing frameworks will apply to urban greenspace studies. Here, I aim to identify which aspects are relevant to urban greenspace studies, highlight which are used and any gaps in the existing frameworks. I highlight these gaps and map the results onto the result from a literature search.

The list of health and wellbeing metrics in this study was adapted from the Valuing Nature Program Demystifying Health publication that created a list of 270 potential health metrics (measures of health determinants, states or outcomes)(Cracknell et al., 2019). These metrics were gathered from a review of 10 reviews including 208 individual studies. They only included studies that took place in a nature-based context. I simplified the list from 270 to 112 metrics by grouping similar metrics based on the following categories; physical and physiological health, mental, psychological or emotional health, social environment or relationships, quality of life, environmental quality, value and connection to people, place or nature and population-level health. I simplified the list of metrics further by listing them grouped by a single outcome and combining multiple metrics to be a single item to score. For example, ‘cognitive function’ was listed as a single outcome but included three different metrics of flexibility, impairment and performance.

Study setting

This study took place in Bradford, a large urban city located in the north of England, United Kingdom, with a population of over 500,000 people (2021 census, Bradford Metropolitan District Council, 2022a). The study took place in three electoral areas (wards): Little Horton, Bowling and Barkerend, and Bradford Moor. These wards are among the 10% most deprived wards in England on the Index of Multiple Deprivation (IMD, 2019). The Better Start Bradford, Better Place Project, aims to improve the community’s health and wellbeing through changing urban greenspaces. The project is focused on under-4-year-olds and expecting mothers and fathers. Interventions include physical changes to urban greenspaces and providing outdoor activities.

Participant recruitment

I aimed to capture the key stakeholder groups that were involved in studying, managing and using the same Bradford greenspaces with similar socio-cultural environments. These stakeholder groups were: academics, delivery partners, community workers, a community member and a member of the local government. Therefore, ten participants were recruited from the Steering Group for the Better Place Project which focuses on under-four-year-olds and the “Join Us: Move Play” (JU:MP) Project (ages 5-11 years) that have overlapping parks and populations in Bradford UK. The steering group had a range of stakeholders including researchers from different disciplines (ecology, public health/epidemiology, physical health and social sciences), local government, and delivery partners. It was recognised that local community members (the greenspace users) should also be involved in this study and recruitment across the Born in Bradford Parents Governors Group through meetings and emails. This study planned to take place with a larger sample size with a wider group of participants from a range of greenspace projects at an in-person workshop. However, due to the COVID pandemic the study was moved online and conducted with a smaller group. As engagement between the Steering Group for the Better Place Project continued throughout the pandemic and therefore provided a suitable online process to conduct a pilot study of the methods and tools intended for the initial study with a larger sample size. The pandemic impacted the ability for people to participate with low uptake from community members. Note, due to the small sample size and restricted number of some stakeholder groups, the conclusions in this chapter are not and should not be applied to wider populations or other greenspace research contexts and the small sample size is made clear throughout the chapter. The ethics approval for this study was given by the University of Leeds (LTSBIO-018).

Data collection

Each participant was asked to rank each of the descriptors or metrics individually between 1 and 9 in terms of the priority for reporting it across all greenspace projects. A score between 1 and 3 indicated low priority, 4 and 6 medium priority, and 7 and 9 high priority, indicating that the descriptor or metric should be reported on in every greenspace project. A score of zero could be given if they did not want to rank that descriptor or metric. Participants were also asked to state if they used any descriptors or metrics in their work and were given the opportunity to comment on any of the items (descriptors or metrics) as well as suggest other descriptors or metrics to add to the list. Each participant had a copy of the survey (see Table 2.1, see supplementary material) and had at least four weeks to complete the survey (online or email back the completed table)(the survey was open from 25 Mar 2022-31 Jul 2022). I also asked participants about their area of expertise, years of experience in their greenspace work or research field and if they were a member of any environmental organisations (such as charities) or a member of community organisations associated with the use or care of greenspaces.

Data analysis

The data was separated from participants' names by replacing the name with a unique, anonymous identifier. The data was processed by aggregating responses from the same stakeholder group (for example using the average scores from four researchers for each item). This approach prevented biasing the overall rankings of items by giving each stakeholder group a single value for each item. Averages were taken across the five stakeholder groups to get the overall rankings for each item. Two stakeholder groups only had one participant (community member and local government) and so raw data were used rather than averages.

I used the stakeholder group averages to explore the overall ranking for each item (descriptor or metric) and to compare each stakeholder group score or average or to individual scores if there was only one participant from that group (Table 2.2). The standard deviation indicated the spread of the scores compared to the overall average. I recognise the small sample size in this study but the sample is representative of greenspace projects of its kind and I wish to share the learning that could inform projects with steering groups of similar sizes and membership. Therefore, I do not apply conclusions to wider populations or other greenspace research contexts and make the small sample size clear throughout reporting of results. Conclusions based on these results are highlighted as being relevant to this study only but recommendations are shared to assist future projects with initiating conversations (about definitions of greenspace and metrics they wish to use in monitoring and evaluation) in steering groups of similar size and stakeholder membership. To measure the reliability of agreement for the level of priority (low, medium or high) across participants (10 raters of 201 items) and five stakeholder groups (201 items) I used Fleiss' kappa (Fleiss et al., 2003). This was appropriate as raters were independent of each other and rated the same number of items with the same number of categories. To interpret the results I used the general categories of agreement from (Altman, 1999) (adapted from (Landis and Koch, 1977)): <0.00 = no agreement, 0.00-0.20 = poor agreement, 0.21-0.40 = fair agreement, 0.41-0.60 = moderate agreement, 0.61-0.80 = good agreement, and 0.81-1.00 = very good agreement. I also examined which of the descriptors or metrics had been used by most participants.

The qualitative data collected in the free text box available for each descriptor or metric was reflected in the ranking data and was dominated by one participant. Therefore, I use quotes from the qualitative data to expand on the ranking of descriptors and metrics rather than present the qualitative data in detail.

Mapping descriptors and Metrics

To place the metrics from this study (sourced from Cracknell et al., 2019 review of reviews) in the wider literature. Therefore, I conducted a literature review for defining greenspace. I searched the literature using the following search terms on SCOPUS on the 30th March 2023 '(TITLE-ABS-KEY (defin*) AND TITLE-ABS-KEY (greenspace))'. I included studies that explored ways to describe or define greenspace. I included articles that defined greenspaces as part of definitions for associated terms; urban ecosystems services, blue space, green infrastructure or nature-based solutions. I excluded studies that did not define greenspaces (n= 9). I screened the articles first by title, then abstract, then full article (n= 486). I excluded articles at each stage (excluded 433 at title and abstract and 9 at full article stages of screening as they were not related to defining greenspace) or if they could not be accessed or accessed in English (n= 1) (see results in Figure 2.1 using the PRISMA method, Page et al., 2021). I carried out a mapping exercise to overlay the descriptors prioritised in this study by stakeholders with descriptors from the literature. Through this exercise, I identified commonalities between the prioritised descriptors and those recommended in the literature but I also highlighted gaps. I, therefore, collate descriptors from multiple sources and combine these with the rankings from the data to offer a list of descriptors that aim to fill gaps in our study from the literature.

To place the prioritised health metrics from this study in the context of the wider literature, I reviewed the source material for the health metrics (Cracknell et al., 2019) to identify the number of reviews and studies that used the prioritised metrics in this study. By identifying these studies, I create an additional resource for readers to build their understanding of the metrics and where they have been applied previously. I also aimed to identify any high-priority metrics that were not included in the source material (either in reviews or individual studies). Please note that I do not suggest that the number of studies associated with a metric denotes the importance of the metric. Instead, it displays the prevalence of use, which may be influenced by other factors such as ease of use or cost of using tools or methods to record that metric.

Table 2.1. List of descriptors and metrics stakeholders were asked to score (1-3: low, 4-6 medium and 7-9 High and 0 if they did not want to score that item). Participants were given the opportunity to add comments and other ideas for each item. Note there were short descriptions for each item, but these have been removed for brevity here. An * indicates where items were added by authors from experience working on urban greenspace projects and were additional to those identified from the literature. See the survey layout in the supplementary material.

	Green space descriptors		**Biodiversity and nature**		**Broader measures for urban greenspaces**
1.	Biodiversity: habitat (number and extent)	2.	*Biodiversity likely to be experienced	3.	*Activities and events organised in greenspaces
4.	Biodiversity: species abundance	5.	Community composition (such as the mix of species and or the interactions between them)	6.	*Area managed for wildlife
7.	Biodiversity: species richness	8.	Ecosystem composition by functional type	9.	*Employment associated with greenspace
10.	Connectivity or fragmentation between greenspaces	11.	Ecosystem functions (Net primary productivity, disturbance regime, nutrient retention)	12.	*Frequency of use the greenspace
13.	Gradient of urbanisation	14.	Extent of habitats	15.	*Length of use of greenspace
16.	Greenspace Landscape	17.	Habitat connectivity and fragmentation	18.	*Naturalness of greenspace (perceived)
19.	Management type	20.	Habitat structure	21.	*Patterns of use
22.	Number of people with access to the greenspace (out of total population)	23.	*Invisible biodiversity	24.	*Social media posts about the greenspace
25.	Ownership	26.	*Perceived biodiversity	27.	*Surrounding land cover
28.	Qualitative description of vegetation mix	29.	*Presence of protected or flagship species	30.	*Types of use for greenspace
31.	Size of greenspace and blue space (area)	32.	*Abundance of functional groups	33.	*surrounding greenspaces at a given scale (number, size, connectivity)
34.	Type of greenspace	35.	Species abundance		
36.	User quality	37.	Genetics		
		38.	Survival rate		
		39.	Traits (such as phenology or morphology, movement and dispersal ability)		
		40.	Species richness		

Ecosystem Services or Nature's Contribution to People		Ecosystem Disservices	
41. Cultivated terrestrial plants for nutrition, materials or energy	42. Lifecycle maintenance, habitat and gene pool protection	43. Animals searching for food in litter bins (presence, abundance, species richness)	44. Areas with natural features that are perceived as unsafe, especially in night-time
45. Cultivated aquatic plants for nutrition, materials or energy	46. Pest control	47. Areas of unpleasant untidy areas of vegetation	48. Certain animal species can be vectors of diseases
49. Reared animals for nutrition, materials or energy	50. Regulation of soil quality	51. Sounds, smells and behaviour of plants and animals perceived as negative by people	52. *Plants and animals are perceived as dangerous
53. Reared aquatic animals for nutrition, materials or energy	54. Water conditions	55. Views blocked by plants	56. Reduced air quality
57. Wild plants (terrestrial and aquatic) for nutrition, materials or energy	58. Atmospheric composition and conditions	59. *Water features that are poorly managed, high biodiversity can be seen as unpleasant	60. *Water features can be seen as unsafe
61. Wild animals (terrestrial and aquatic) for nutrition, materials or energy	62. *Carbon storage	63. Costs are caused by attempts to remove unwanted species	64. Wild or semi-wild animals in larger park areas can cause fear, anxiety and inconvenience.
65. Genetic material from plants, algae or fungi	66. Physical and experiential interactions with natural environment (active, passive, immersive, observational)	67. Damage to structures	68. Presence of protected species restricting use of the area
69. Genetic material from animals	70. Scientific or traditional ecological knowledge: intellectual and representative interactions with natural environment	71. Harmful species (can damage those species that are cared for and thus cause economic loss)	72. *Uneven ground or muddy areas
73. Provisioning (Biotic): Other types of provisioning service from biotic sources	74. Education and training: Intellectual and representative interactions with natural environment	75. Maintaining costs (such as planting and removing)	76. Large green or blue areas can obstruct fast and convenient transportation
77. Surface water used for nutrition, materials or energy	78. Culture or heritage: Intellectual and representative interactions with natural environment	79. Reduction in property value	80. Visibility issues from vegetation
81. Ground water for used for nutrition, materials or energy	82. Aesthetic experiences: Intellectual and representative interactions with natural environment	83. Alteration of soil fertility and nutrient flow	84. Green waste, leaf litter, debris, falling tree, branches

85. Mediation of wastes or toxic substances of anthropogenic origin by living processes (such as pollution)	86. Spiritual, symbolic and other interactions with natural environment	87. Decrease in water quality/quantity	
88. Mediation of nuisances of anthropogenic origin (such as smell)	89. Other biotic characteristics that have a non-use value	90. Displacement of native or endemic species	
91. Regulation of flows and extreme events	92. Other characteristics of living systems that have cultural significance	93. Introduction of non-native and or invasive species	
94. *Economic benefits	95. *Space to meet, socialise or exercise	96. Reducing species diversity	
97. *Varying topography		98. Allergies or intoxication	
Health and wellbeing			
99. Allergies (prevalence and/or severity)	100. Falls	101. Attention deficit hyperactivity disorder (ADHD)	102. Spiritual well-being
103. Antibodies (levels/presence)	104. Fine motor ability	105. Anxiety	106. Eudaimonic well-being
107. Asthma	108. General health	109. Craving (or either addictive or non-addictive substances)	110. Self-awareness
111. Brain activity	112. Heart health	113. Depression (cases, symptoms, perceived, coping)	114. Self-esteem or self-worth
115. Breathing	116. Hospitalisation	117. Mental Health Disorders	118. Self-efficacy
119. Blood pressure (Systolic BP/Diastolic BP, hypertension, arterial stiffness)	120. Human parasite abundance	121. Medication	122. Aspirations
123. Body awareness	124. Infection rates	125. Psychological distress	126. Attention (on surrounding environment, deficit, engagement, inattentiveness)
127. Baby's health in first 5 mins	128. Life expectancy	129. Post-traumatic stress disorder (PTSD)	130. Cognitive (flexibility, impairment, performance)
131. Birth weight and gestational age	132. Microbiota (such as skin or nasal microbes)	133. Vitality	134. Learning
135. Baby head circumference at birth	136. Mobility	137. Resilience	138. Memory (verbal, visual, superior working memory)
139. Child development	140. Nutrition	141. Mindfulness	142. Reaction time
143. Cancer (such as risk, cases, coping)	144. Obesity	145. Mood (positive/negative)	146. Processing and Psychomotor speed

147. Cholesterol	148. Pain/discomfort	149. Emotions (enjoyment, happiness, loneliness)	150. Motor vehicle fatalities
151. Chronic obstructive pulmonary disease (COPD)	152. Physical activity	153. Stress (perceived, parenting, attentional fatigue)	154. Play (constructive, functional, symbolic
155. Dementia	156.		157. Aggression
158. Diabetes	159. Births		160. Agitation
161. Dopamine	162. Number of chronic conditions		163. Arousal
164. Physical fitness	165. Number of years lost due to ill-health, disability or early death	166. Social value of green infrastructure	167. Problematic behaviours
168. Respiratory disease	169. Prevalence of asthma	170. Proximity to greenspace	171. Punishment and reward sensitivity
172. Sleep (amount, quality)	173. Prevalence of osteoporosis	174. Environmental awareness/identity	175. Risk taking
176. Restorativeness (including attention restoration theory)	177. Deaths	178. Quality of greenspace	179. Sensation seeking
180. Self-reported wellbeing	181. Health inequalities	182. Social return on investment for public health interventions	
183. Feelings about behaving in healthy ways	184. Heat-related excess mortality (in the elderly)	185. Number of visitors to greenspace	
186. Confidence	187. Belonging (Neighbourhood belonging)	188. Environmental value of green infrastructure	
189. Creativity	190. Community-connectedness	191. Neighbourhood satisfaction	
192. Decision making	193. Social inclusion	194. Quality Adjusted Life Years (QALYs)	
195. Empathy	196. Relationships with others (partners, children, family, friends, parent and baby, social skills, social capitol, family functioning, risk of abuse)	197. Standard of living/Material wellbeing	
198. Habitual behaviours	199. Social trust	200. Relationship with nature (connection to, affinity to, nature relatedness, inclusion of self in nature)	
201. Impulses	202. Achieving in life/Personal development	203. Economic value of green infrastructure.	
204. Motivation	205. Crime	206. Life satisfaction	

2.4 Results and Discussion

Study Sample

The study participants from the Steering Group for the Better Place Project (n= 10) captured a range of stakeholder perspectives, this included (Table 2.2):

- *academics* focusing on intervention design from different disciplines (public health/epidemiology, physical health) (n= 4)
- *delivery partners* that managed the project and implemented changes to the urban greenspaces (n= 2)
- *community workers* that are responsible for community engagement and behaviour-related interventions (such as running outside story times) (n= 2)
- *community member* who was a parent of a 0-3-year-old living in the study area and used the greenspaces (n= 1)
- *local government* who are responsible for maintaining the greenspaces (n= 1).

All participants reported at least 5 years of experience in their field of expertise (average of 15.6 ± 10.3 SD years, n= 10), with the most experienced having 35 years in their field. Only two participants (20%) were members of a member of any environmental organisation or network (such as wildlife charities or local groups). Three participants (30%) were members of any community organisation associated with the use or care of neighbourhood greenspaces.

Table 2.2 Summary statistics of the sample population (n=10). The stakeholder group and individual experiences are displayed.

No	Stakeholder group	Area of expertise	Years of experience in this field	Member of environmental organisations	Member of community organisation associated with the use or care of greenspaces
1.	Academic	Ecology	17	No	No
2.	Academic	Health (epidemiology and evaluation)	20	No	No
3.	Academic	Health (physical activity research and intervention design)	14	No	No
4.	Academic	Community engagement, and social science research	7	No	No
5.	Delivery partner	Programme management of greenspace projects	9	No	Yes
6.	Delivery partner	Landscape design, community engagement	35	Yes	Yes
7.	Community worker	Community Engagement and ecology	8	Yes	Yes
8.	Community worker	Park Ranger, Maintenance, Forest School Practitioner	5	No	No
9.	Community member	Parent	10	No	No
10.	Local government	Park & greenspace management	31	No	No
		Total	156	2	3
		Average	15.6		
		Standard deviation	10.3		

Finding consensus in greenspace descriptors and metrics

There was fair agreement across stakeholders for all items (descriptors and metrics combined into an overall list) (Fleiss Kappa = 0.22, p<0.001) (Table 2.3). There was also fair agreement for those ranked as high (stakeholders thought these should be reported in every project) (Fleiss Kappa = 0.32, p= <0.001) and low (those not necessary to report in all projects) (Fleiss Kappa = 0.28, p=<0.001). However, unsurprisingly there was poor agreement for those descriptors or metrics given medium priority (these are seen as potentially useful to report in all projects but not necessary) (Fleiss Kappa = 0.18, p=<0.001). This is to be expected from a group of stakeholders from different disciplines as the medium metrics (e.g. air quality) may be more discipline-specific compared to the widely-supported high-importance metrics (e.g. green space size) or the widely-disregarded low-importance metrics (e.g. cultivated plants or animals).

Table 2.3 Fleiss Kappa results across all items (descriptors and metrics), descriptions and metrics. Prioritisation scores were as follows, low 1-3, medium 4-6 and high 7-9.

	Prioritisation	Subjects	Raters	Kappa	Level of agreement or disagreement	P
Full List	All Items	201	5	0.22	Fair agreement	**<0.001**
	High			0.30	Fair agreement	**<0.001**
	Medium			0.18	Poor agreement	**<0.001**
	Low			0.28	Fair agreement	**<0.001**
Descriptions	All Items	12	5	0.13	Poor	0.10
	High			0.18	Poor agreement	**0.05**
	Medium			0.12	Poor agreement	0.21
	Low			-0.53	Moderate disagreement	0.56
Metrics	All Items	189	5	0.21	Fair agreement	**<0.001**
	High			0.19	Poor agreement	**<0.001**
	Medium			0.18	Poor agreement	**<0.001**
	Low			0.28	Fair agreement	**<0.001**

Describing urban greenspaces in projects

Stakeholders were asked to rank descriptors of greenspaces that should be reported as a standard practice for greenspace projects. Six descriptors scored highly (7-9) across stakeholders and would make up the standard set for describing urban greenspaces. The descriptors were 1) type of greenspace, 2) user quality, 3) size of green (and blue) space, 4) ownership (such as public/private), 5) number of people with access (such as a percentage of the total area population) and 6) habitats in the greenspace (Table 2.4). The descriptors ranked highly are multidisciplinary, combining social and ecological elements. Although the level of agreement was poor (Fleiss Kappa = 0.18, p = 0.05), it is likely that consensus would be harder to find among multiple disciplines with varied interests for the same greenspace (Table 2.3).

The remaining descriptors suggested for standard reporting scored an average of five and above and would be recommended alongside the core standard set that scored high (Table 2.4). These were also multidisciplinary but required additional data or analysis (such as connectivity or fragmentation of greenspaces). For those with medium ranking, there was poor but not significant agreement between stakeholders (Fleiss Kappa = 0.12, p= 0.21; Table 2.3).

For those ranked low, there was moderate disagreement but this was not significant (Fleiss Kappa = -0.53, p= 0.56, Table 2.3).

All stakeholders (n=10, 100%) used the type of greenspace and prioritised this for the core set of descriptors. This contrasts the review of 125 journal articles by (Taylor and Hochuli, 2017) where greenspace type was not reported often (n= 5 of 125 journals reported greenspace type). However, the definition I use in this study overlaps more with the 'definition by example' category which was used in 17 of 125 journals reviewed by (Taylor and Hochuli, 2017) and was the second most common dimension described in studies included in the review by (Hunter and Luck, 2015)(n = 72% of 50 journals articles). This is perhaps the simplest descriptor and therefore it should be described in all projects. However, I recognise that cultural context may lead to varied interpretations so further descriptors should be used alongside greenspace type to offer more precision. I would not recommend describing the type of greenspace in isolation from other descriptors.

User quality was the next most used descriptor (90%, n= 9 of 10). In the context of this study for greenspace quality, I gave examples of facilities for users (such as benches or paths), the absence of unpleasant items (litter or dog poo) as well as biodiversity. The high priority and high use of user quality descriptors display the interdisciplinary aspect of greenspace projects. However, the term greenspace quality needs defining further in each study as it is a broad term and can encompass many dimensions of greenspace (physical, biotic, abiotic, management and recreation) (Hunter and Luck, 2015; Taylor and Hochuli, 2017).

Size of greenspace and blue space was also ranked high priority and use (with 70%, n= 7 of 10 using this metric). This supports the recommendations of (Hunter and Luck, 2015; Taylor and Hochuli, 2017) to describe the physical dimensions, including the size of an area. Access to greenspace and ownership was also used by most of the participants (70%, n= 7 of 10 and 60%, n= 6 of 10), reaffirming that urban greenspace projects often have a human element.

Mapping descriptors to existing literature

The results from the literature search are summarized in Figure 2.1 using the PRISMA method (Page et al., 2021). It is clear that the definition of greenspace varies greatly across studies (n= 33). Results from the literature search complimented the findings from this study by highlighting the interdisciplinary nature of urban greenspaces with aspects of definitions including environmental, ecological and social elements. A key emerging theme from the literature was that greenspaces were often defined as being in urban areas and the relationship with human intervention was an important element of this definition. Examples included defining urban greenspace as land that is not developed or built on (La Rosa and Privitera, 2013; Mu and Li, 2020), vegetation having proximity to buildings of particular heights (Gupta et al., 2012) and being positioned close to or dispersed within human settlements (Amarawickrama et al., 2015; Lai et al., 2019; Niedźwiecka-Filipiak et al., 2022)). Indeed 10 studies defined greenspaces based on their relationship with urban features (Table 2.5). Greenspace type or land cover were part of definitions of greenspace for 6 of the articles, this compliments the most prioritised descriptor in this study. Size was another physical characteristic with a high priority for the participants and this was explored in the definition of greenspaces in 4 studies.

The social element of urban greenspace was highlighted by both the participants and literature. For example, access to greenspace was a theme across 12 of the studies and a key descriptor for the participants in this study. User quality of greenspace was the second most important descriptor for the participants and was complemented by 5 studies including this in their definition of urban greenspaces, with particular focus on amenities for greenspace users. However, quality also included multiple dimensions of safety, attractiveness and biodiversity.

Aspects of biodiversity such as species richness, habitat connectivity and species abundance were prioritised in the list and a common theme from 19 studies. Vegetation mix or type was particularly highlighted as important for greenspace definitions in 8 studies and prioritised in the list form out participants. Habitat number and extent were in the highest scoring descriptors in and complimented by the literature with 5 studies including this element in their definition of greenspace. The connectivity of greenspaces as highlighted as important by participants and the literature (7 studies) and often with a dual purpose for people and nature to move between greenspaces.

Some dimensions of greenspace definitions from the literature were not covered by the list of priority descriptors from the participants (see Table 2.10 supplementary material). These included themes of ecosystem services and safety. However, these were prioritised metrics by the participants for evaluating greenspace projects (see Table 2.6). Some other key themes from the literature such as defining greenspace by greenness or land cover were not included in either list of descriptors or metrics. However, I would recommend that these, particularly the most commonly used measure, the Normalized Difference Vegetation Index (NDVI), is included in future greenspace studies as this helps to collate evidence if this metric is used alongside other greenspace metrics (Rojas-Rueda et al., 2021). Another gap is to explore ways of defining people's engagement with urban greenspace which is a key part of many greenspace projects, Jerome et al. (2017) offer a framework for defining this and how it relates to longevity of greenspace projects or maintenance.

One recommendation to emerge from this exercise and literature was how using the one-word compound of greenspace could help with collation of evidence (Taylor and Hochuli, 2017). The one-word compound is preferred because it is easier to distinguish from the noun phrases (green + anything, for example, *green paper*, or space + anything which could be referring to *outer space*). One study that was returned from the search demonstrated how using the two-word version of greenspace could increase the number of irrelevant results. The paper in question that was picked up by the search was '*Greenspace: Towards a systematic, global and innovative evaluation of the environmental impact of space activities for a safe and sustainable space environment*' (Consonni et al., 2014). This paper is not about greenspace in urban areas, although the authors' use of the greenspace compound complicates the results it is clear if I had not used the one-word compound the search may have returned more space-related papers.

The results aligned with the previous literature (see Table 2.5). Therefore, I would recommend that the following descriptors are used in every greenspace project, as they have been given high priority and have high use across multiple stakeholders:

- definitions, descriptions and examples of the types of greenspace
- the physical characteristics relating to user quality (including amenities, recreation and undesired features (unsafe areas, litter, graffiti)
- physical characteristics that include the size of greenspace but also the contextual setting of the greenspace
- ownership and management (is it publically owned and managed for the public, and if so what is the intensity of management)
- Access to greenspace (although there is no clear consensus on a metric for this, it is often measured as a number or area of greenspace in a set distance from a person's home but there isn't an internationally recognised optimum distance (Browning and Lee, 2017) so this should be applied at a relevant scale for the study question
- Ecological information relating to habitats (their size and mix)

I would also recommend if possible (and appropriate) that the following to be described in all greenspace studies:

- the spatial context of greenspace in relation to other greenspaces and urban areas including connectivity (although the scale will differ across projects as to if local, regional, or national so contextualisation is important) and the level of urbanisation surrounding the greenspace should be included in this description.
- describe the biotic elements of a greenspace (such as the vegetation mix including trees, species richness and species abundance).

The list did not include the descriptors of tree cover, socio-cultural descriptors, temporal land use change or designation of greenspace (Table 2.5). Therefore, I have no available evidence from this study on the priority or consensus surrounding their importance or use so I would advise stakeholders to make their own assessment of when to include these metrics. I recognise their value and do not recommend discarding their use but instead for future studies to gather similar evidence on use, priority and consensus across multiple stakeholders. There is clear evidence that the surrounding social context of a greenspace (such as population density and anti-social behaviour) can influence use (Lo and Jim, 2010; Fischer et al., 2018b; Cronin-de-Chavez et al., 2019). Jarvis et al. (2020) demonstrate that access does not guarantee exposure to (use of) greenspaces and the associated health outcomes. Therefore, I would argue that access is not explored in isolation from socio-cultural descriptors and greenspace exposure (use) when investigating health and wellbeing-related research questions.

Mcintyre et al. (2000) expands this by stating that the urban environment is both a physical and a social entity in its creation, studies need to combine natural and social sciences. In fact, social sciences describe urban areas in relation to population but ecologists refer to these as areas of high human influence (such as buildings). Population density can shape the built environment, for example, a recent study of 68 UK city centres found that population size was negatively associated with greenness and tree coverage (Robinson et al., 2022). This is why Mcintyre et al. (2000) argue that baseline descriptions of urban environments (which are usually present in urban greenspace projects) should include demography, socioeconomic, and cultural factors. Mcintyre et al. (2000) also suggest having regular pictorial evidence of the study environment as people's perceptions will change over time, and this will influence the cultural context of the community close to the urban greenspace. This is similar to 'shifting baseline syndrome' in ecology where the absence of past information or experience, new generations accept their situation as the norm, overlooking previous conditions (which may have had different habitats or species compared to present day situation) (Soga and Gaston, 2018). Mcintyre et al. (2000) and Voghera and Giudice, (2019) also recommend describing energy networks as the amount of energy used per unit area per year for the study environment as the level of energy used in urban systems is magnitudes greater than other ecosystems and so a defining feature of urban systems (Odum, 1997). Therefore, I would recommend that projects take into account social elements of greenspace studies in urban environments such as:

- demography
- socioeconomic
- cultural factors
- energy use
- changes to the system over time (using visual references)
- Transport networks and traffic

I recognise their value and would advise stakeholders to make their own assessment of when to include these metrics.

Applying recommended descriptors to greenspaces in the Better Start Bradford area

I applied the recommendations to a worked example where I use the high-priority descriptors (Table 2.4) and additional recommended descriptors from the literature to describe greenspaces in the study area. I present the data for type of greenspace, a description of the greenspace, the size of the greenspace, the ownership of the greenspace, user quality of the greenspace and biodiversity (species richness and a qualitative indication of habitats) in Table 2.11 supplementary material. I collected abundance for areas of the larger parks included in a different study on biodiversity and physical activity but the way the data is collected means it doesn't lend itself to scaling up to the whole greenspace level and was also not available for all greenspaces. For insights into the practicalities and feasibility of collection, this data is discussed in 6. General Discussion of this thesis. A map of the greenspaces can show the spatial context of the greenspace (see Figure 2.2 in supplementary material).

Assessing access to greenspace was possible through data for the study population, those part of Born in Bradford's Better Start (BiBBS) cohort (Dickerson et al., 2016) and Born in Bradford (BiB) cohort (Wright et al., 2013). Access to particular types of greenspaces in Bradford was explored by Ferguson et al. (2018).

When exploring the human element environment, the demography, socioeconomic and cultural factors are described in the text for each study that uses this greenspace data. Research on greenspaces within the study area is also described (Dadvand, Wright, et al., 2014; McEachan et al., 2016; Wood et al., 2018; McEachan et al., 2018; Ferguson et al., 2018; Cronin-de-Chavez et al., 2019). One study in particular explored the barriers and enablers for community members to use the local greenspaces in the study area (Cronin-de-Chavez et al., 2019). I did not explicitly collect data on changes to the urban environment over time such as past greenspace use or locations but participants in this study on greenspace use highlighted past use or features that had changed over time. Local organisations with local knowledge of greenspaces over the years were engaged in co-design of greenspaces to help integrate past use and offer pictorial references of spaces (as suggested by (Mcintyre et al., 2000).

When describing the other features of the urban environment such as energy, traffic and networks it was more difficult for the study area with less readily available data on energy use in the study area. I did not collect or use data on energy use per household or across the study area.

As for the transport networks, I can describe the area by types of roads (n= 4,689; 287.70 km) using data from OS Open Roads layers (Ordnance Survey Limited, 2021b), there were 9 motorways, 397 A roads, 49 B roads, 1213 minor roads, 2646 local street roads, 349 primary roads, 7 pedestrianised streets and 19 private roads with public access.

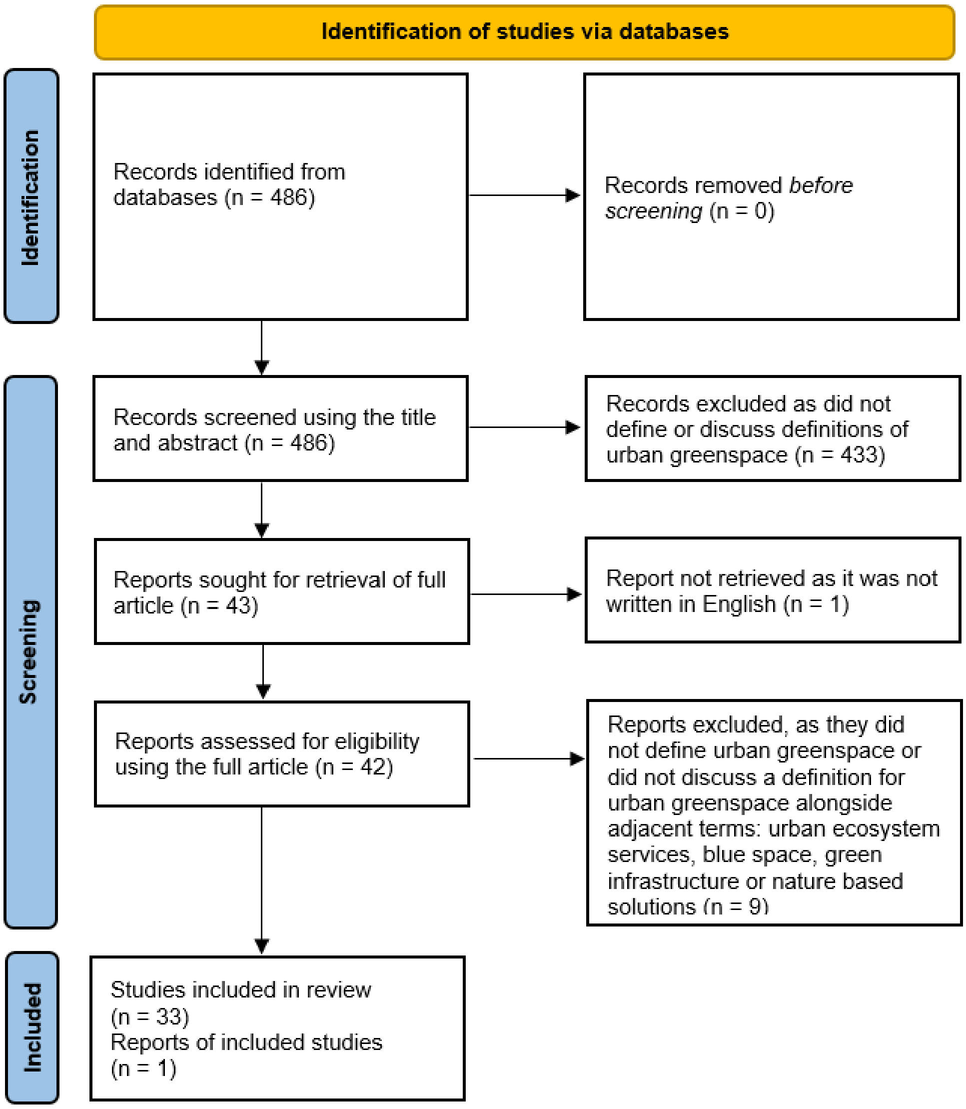


Figure 2.1 Articles included and excluded from the search of SCOPUS ((TITLE-ABS-KEY (defin*) AND TITLE-ABS-KEY (greenspace)) on the 30th March 2023 displayed using the PRISMA flowchart method (Page et al., 2021)

Table 2.4. The descriptors organised by highest average ranking across stakeholder groups and the score for each stakeholder group (n=10). Participants also indicated if they used this descriptor in their work. Those above the line scores 7 or above and therefore deemed as high priority and had some consensus (poor level of agreement, Fleiss Kappa = 0.18, p = 0.05), across stakeholders to report in all greenspace projects.

					Stakeholder Group (n)				
	Descriptor	**Score (AVG)**	**SD**	**USE (total)**	**Community member (1)**	**Community worker (2)**	**Delivery partner (2)**	**Local government (1)**	**Researcher (4)**
1	Type of greenspace	8.6	0.7	10	8	8.5	9	9	8.5
2	User quality	8.4	1.3	9	9	7	9	8	8.75
3	Size of greenspace and blue space (area)	7.8	2.0	8	9	7.5	9	7	7.25
4	Ownership	7.4	2.1	6	3	7	7.5	9	8.25
5	Number of people with access to the greenspace	7.3	1.8	7	4	7	8.5	7	7.75
6	Biodiversity: habitat (number and extent)	7.1	1.0	5	6	7.5	8	6	7
7	Management type	6.7	1.9	5	9	6.5	8	9	5
8	Greenspace Landscape	6.6	2.8	5	8	7.5	9	8	4.25
9	Gradient of urbanisation	6.5	1.9	3	2	7.5	7	8	6.5
10	Qualitative description of vegetation mix	6.4	1.9	5	5	6.5	8	7	5.75
11	Biodiversity: species richness	6.2	2.4	5	7	7.5	8	6	4.5
12	Connectivity or fragmentation between greenspaces	5.8	2.6	5	3	7	8	7	4.5
13	Biodiversity: species abundance	5	2.7	4	0	6.5	7	6	4.25

Table 2.5 Ranked descriptors from this study compared to wider literature for describing urban greenspaces. This highlights areas of overlap from the study to wider literature but also the areas where the list could be extended further. Those to the left of the line scored 7 or above and therefore deemed as high priority and had some consensus (poor level of agreement, Fleiss Kappa = 0.18, p = 0.05), across stakeholders to report in all greenspace projects.

Descriptor	**Type of greenspace**	**User quality**	**Size of greenspace and blue space (area)**	**Ownership**	**Access greenspace**	**Habitat (number and extent)**	**Management type**	**Greenspace Landscape**	**Gradient of urbanisation**	**Qualitative description of vegetation mix**	**Species richness**	**Connectivity or fragmentation between greenspaces**	**Species abundance**
Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Taylor and Hochuli, 2017	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	-	Y
Hunter and Luck, 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mcintyre et al., 2000	Y	-	-	Y	-	-	-	-	Y	-	-	-	-
Royer et al., 2023	-	-	-	-	-	-	-	-	-	-	-	-	-
Jalkanen and Vierikko, 2022											Y	Y	Y
Robinson et al., 2022	-	-	-	-	Y	-	-	-	-	-	-	-	-
Niedźwiecka-Filipiak et al., 2022	-	-	-	-	-	-	-	-	Y	-	-	-	-
Koh et al., 2022	-	-	-	-	-	-	-	-	-	-	-	-	-
Matsler et al., 2021	-	-	-	-	-	-	-	-	Y	-	Y	-	-
Castellar et al., 2021	-	-	-	-	-	-	-	-	-	-	Y	-	Y
Rojas-Rueda et al., 2021	-	-	-	-	-	-	-	-	-	Y	-	-	-
Klaus and Kiehl, 2021	-	-	-	-	-	-	-	-	-	-	Y	-	Y
Delgado-Capel and Cariñanos, 2020	Y	-	-	-	Y			-	-	-	-	Y	-
Seiwert and Rößler, 2020	-	-	-	-	-	-	-	-	-	-	-	Y	-

Mu and Li, 2020	-	-	-	-	-	-	-	-	Y		-	-	-
Im, 2019	Y	-	-	-	-	-	-	-	-	Y	-	-	-
Knobel et al., 2019	Y	Y	-	-	Y	-	-	-	-	-	Y	-	-
Lai et al., 2019	Y	-	-	-	-	-	-	-	Y	Y	-	-	-
Soltanifard and Jafari, 2019	-	-	-	-	-	-	-	-	-	-	Y	-	Y
Pregitzer et al., 2019	Y	-	-	-	-	-	Y	-	-	Y	-	-	-
Voghera and Giudice, 2019	-	-	-	-	Y	-	-	-	Y	-	Y	Y	-
Corley et al., 2018	-	Y	-	-	Y	-	-	-	-		Y	-	-
Klompmaker et al., 2018	-	-	-	-	Y	-	-	-	-	-	-	-	-
Farinha-Marques et al., 2017	-	-	-	-	-	Y	-	-	-	-	Y	Y	Y
Jerome et al., 2017	-	-	-	-	-	-	-	-	-	-	-	-	-
Perchoux et al., 2016	-	-	-	-	Y	-	-	-	-	-	-	-	-
Amarawickrama et al., 2015	-	-	-	-	-	Y	-	-	Y	-	-	-	-
Rupprecht and Byrne, 2014	Y	-	-	-	-	-	-	-	-	Y	-	-	-
Yao et al., 2014	-	Y	Y	-	Y	-	-	-	-	-	-	-	-
La Rosa and Privitera, 2013	-	-	-	-	-	Y	-	-	-	Y	-	-	-
Gupta et al., 2012	-	-	Y	-	Y	-	-	-	Y	-	-	Y	-
Feest et al., 2009	-	-	-	-	-	-	-	-	-	-	Y	-	-
Doick et al., 2009	-	-	-	-	Y	-	-	-	-	-	Y	-	-
Total	**9**	**5**	**4**	**3**	**12**	**5**	**2**	**2**	**10**	**8**	**13**	**7**	**7**

High-priority metrics for urban greenspace studies

There was fair agreement across stakeholders for the overall rankings of the greenspace metrics (Fleiss Kappa = 0.21, p= <0.001) and those with low priority (Fleiss Kappa = 0.28, p= <0.001; Table 2.3). There was poor agreement for those ranked high (Fleiss Kappa = 0.19, p= 0.56) and medium priority (Fleiss Kappa= 0.18, p= 0.56; Table 2.3), which indicates that the stakeholders have more agreement about the lowest priority metrics for greenspace projects but had more variation their views on priority metrics. Participants suggested no new metrics to add to the list.

The high-priority metrics are interdisciplinary, including metrics from social, ecological, environmental, psychological, and physical and public health disciplines (Table 2.6 and Table 2.8). This supports the concept that urban greenspaces are both social and ecological constructs (Mcintyre et al., 2000). A quarter of high-priority metrics were under the theme of environmental quality, value and connection such as quality of greenspace, number of visitors to greenspace, social value of green infrastructure, relationship with nature, proximity to greenspace, environmental value of green infrastructure and environmental awareness/identity. Another quarter of high-priority metrics were mental, psychological or emotional metrics (including depression, play (constructive, functional, symbolic), anxiety, self-reported wellbeing, mood (positive/negative), stress and mental health disorders. The high-scoring metrics highlight consensus across stakeholders that the natural environment and connection to or use of can influence health and wellbeing. The link between access to greenspaces and health and wellbeing has consistently been recognised by the National Health Service (NHS) and the UK Government in numerous policies (such as Childhood Obesity Strategy or Clean Air Strategy) (see review for further details (Public Health England, 2020). This link is also recognised on the international context with the United Nations Sustainable Development Goal including Target 11.7 on providing universal access to safe, inclusive and accessible, green and public spaces (United Nations, 2022). Therefore, the high priority given to these metrics is not unexpected as international and national policy is realised at the local level in urban greenspace management. However, there is no standardized method to measure time spent in nature or nature contact and multiple definitions of nature contact but the studies in Table 2.5 offer a starting point (Holland et al., 2021).

For the physical and physiological health outcomes listed, a researcher said that '*these factors are important to be considered when investigating the link between greenspace usage and health. Physical health conditions are key cofounders which a lot of the time are not considered* *in the literature of again the link between green space and health*'. This is supported by growing awareness in the literature of confounding variables, such as higher quality greenspace or greater access being associated with areas that are more affluent and therefore health outcomes may be higher in these areas anyway (Lovell et al., 2014; Robinson et al., 2022). Houlden et al. (2017) detail some possible confounding variables from a literature review, these included gender, marital status (single/unmarried, married/civil partnership, and separated/divorced/widowed), ethnicity (white British, white other, black, South Asian, other), and total number of serious on-going physical health conditions, employment status (unemployed, employed and economically inactive), household income, household space (bedrooms per person, living alone, living with children, and housing tenure. Using the English Index of Multiple Deprivation (IMD) can integrate multiple domains relevant to these confounders (Ministry of Housing, Communities & Local Government, 2019): income deprivation, employment deprivation, education, skills and training deprivation, health deprivation and disability, crime, barriers to housing and services and living environment deprivation. However, when people with low access to greenspace use greenspace they can experience similar health benefits to those with good access to greenspace, the use of greenspace is the key factor (Cox et al., 2018).

Metrics that had low priority across stakeholders included ecosystem services (provisioning biomass, genetic services and water) and disservices such as impacts on transport or green waste, and more specialised health metrics (such as baby's health in first 5 minutes, cravings or skin microbiota)(Table 2.6). The study participants were asked about urban greenspaces in the UK, but provisioning ecosystem services might be of a higher priority in other systems, such as rural community greenspace.

Highlighting further the social value of greenspaces, the metric that was most used by the range of stakeholders was the 'number of activities/events held in greenspaces' (9 of 10 people used this metric in their work) and 18.5% of top metrics were based on social metrics (Table 2.6). The top five metrics focus on how people use greenspaces (quality, activities, visitors, space to meet and frequency of visits). For a community worker participant, they said that the distribution of greenspaces and the use of these was important to understand as a baseline to compare changes to throughout their project as it involved both physical changes to spaces as well as behaviour change interventions. The following metrics were used by most stakeholders in their projects: activities and events organised in greenspaces, size of greenspace and blue space (area), frequency of use the greenspace, ownership and area managed for wildlife. These perhaps link to direct outcomes of the project related to the study, which was aiming to improve health and wellbeing through urban greenspace facilities and wildlife.

Wildlife can play a key role in urban greenspaces. For example, a community worker participant identified recording connection to nature (physical, scientific, traditional, educational, cultural, aesthetic, and spiritual) as vital to their project as they aimed to increase these connections. The community worker also wanted to measure biodiversity and monitor if biodiversity was increased through their interventions. This is supported by growing evidence that exposure to nature can offer benefits for health and wellbeing (Lovell et al., 2014; White et al., 2019; Public Health England, 2020; Marselle et al., 2021). For example, a study in the UK found that wellbeing was associated with spending 120 min a week in natural spaces (White et al., 2019). However, participants also acknowledged the disservices associated with the wildlife. The community worker stated that *'high biodiversity is important, but many families may perceive areas as untidy or unsightly, particularly if there are rats'*. This was supported by the community member saying that it's '*not appealing to visit if food on the floor, or bad smell unpleasant if dog poo on shoes, bad smell, flies'*. The community worker also wanted to identify if there were any harmful plants in areas where children play. A delivery partner raised that '*nettles, brambles, thistles would be an issue for 0-3s*'. This is supported by literature on vegetation in urban greenspaces, as park users prefer 'half open' parks compared to areas of dense vegetation, as being able to see through vegetation helps people feel safe and densely vegetated areas are perceived as encouraging anti-social behaviour (Schroeder and Anderson, 1984; Burgess, 1995; Jorgensen et al., 2002; Bell et al., 2003; Jansson et al., 2013; Qiu et al., 2013; Birch et al., 2020). As for leaf debris as a disservice, only one community member commented and said that it was a natural process. While the other community worker raised a concern that varying topography can have implications for fire risk.

Play was a metric that was ranked as a high priority for greenspace projects which is unsurprising as the participants are from a steering group that looks at improving urban greenspace for children. Therefore, I acknowledge that this could be a project-specific result but that it may also hold true in other contexts as urban greenspaces often provide some kind of play function (either formal playgrounds or open spaces to play). A community worker participant identified natural materials, water features and varying topography as opportunities for natural play for children. This is supported by evidence that outdoor spaces offer opportunities for experimental learning and rich sensory experience and a diversity of play which can play an important role in their development (O'Brien and Murray, 2007;

Whitebread, 2017; Beery and Jørgensen, 2018; Coates and Pimlott-Wilson, 2019). Water features in particular are one of the most popular activities children participate in on visits to urban greenspaces (Bozkurt and Woolley, 2020).

There are metrics with high priority across multiple stakeholders but have low use. These are areas that stakeholders would like to be explored across greenspace projects. These include the economic and social value of greenspaces and mental health metrics (anxiety, self-reported wellbeing, mood and stress). These metrics are less readily available but tools such as the Outdoor Recreation Valuation (ORVal) tool could help (Day and Smith, 2018). The tool helps to explore the distribution of greenspace across England and Wales and the associated estimated visits and welfare value of these greenspaces (Day and Smith, 2018). It can also explore changes in visits to greenspace and the value of creating new greenspace. A community worker participant said '*could be useful to know how greenspaces save money on health services - particularly for families with babies and toddlers'.* There is value in this line of research but Dobson (2018, p. 77) warns that 'by reducing urban nature to a health intervention alone, its value becomes subject to a narrow measure of cost-effectiveness for a particular population cohort. Policymakers and local decision-makers are left with a dilemma: to continue to invest in green and natural spaces in the belief that not doing so will lead to unspecific but keenly felt negatives in terms of everyday human functioning, or to reduce investment in order to focus on immediate threats to life.' I agree with (Dobson, 2018) and would recommend that the value of greenspaces is communicated as enabling good health and wellbeing and that absence of evidence of the underpinning mechanisms shouldn't act as a barrier to continued investment. Indeed a study across five European cities, found that their participants (N=3716) consistently expressed that higher plant species richness is an enabling factor for more liveable cities, offering an added value in relation to simply green spaces (with lower biodiversity)(Fischer et al., 2018a).

Crime was also seen to be important but used by fewer of the stakeholders used this (3 of 10), perhaps because using a secondary data source (which is widely available in the UK but may vary in quality) is a barrier to using this data. Although studies may find using the Index of Multiple Deprivation can integrate local crime statistics along with local education and income (Ministry of Housing, Communities & Local Government, 2019). A community member supported the importance of this metric as they described aggressive behaviour as a barrier to the use of greenspaces and that friendliness between park users should be included too. As highlighted earlier in this paper, access to greenspace doesn't always equate to use of greenspace because other individual or social barriers may remain (Lo and Jim, 2010; Cronin-de-Chavez et al., 2019; Jarvis et al., 2020). On the other hand urban communities with higher residential greenness can have a stronger sense of community (Cox et al., 2018).

Mapping metrics to existing literature

I do not support vote counting (attributing greater value to the metrics with the highest number of studies), instead, I wanted to compare the prioritised metrics from stakeholders in this study with the wider literature on metrics. I compared the priority metrics in this study to the reviews (n=10) and studies (n= 208) that were the basis for the list of metrics in Cracknell et al. (2019). From those metrics with a high priority for the stakeholders, physical activity was the most frequently explored (in five reviews and 19 individual studies), then wellbeing (in eight reviews, 18 individual studies), then stress (five reviews and 12 individuals studies), anxiety (five reviews and eight individual studies), depression (4 reviews and 8 individual studies), mood (three reviews and six studies), relationships (three reviews and in five individual studies) and finally play (one review and one individual study; Table 2.7). Nature connection and environmental awareness and economic value of greenspaces were not included in reviews or the associated individual studies.

I recognise that greenspace studies will have different focuses and requirements for what they measure depending on their discipline and research questions. However, I highlight metrics that would have relevance across multiple disciplines (which are often involved in greenspace projects). If these metrics were reported in future greenspace studies it could help with evidence synthesis, particularly in times where there are limited resources available for greenspace research and management. Therefore, I would recommend that urban greenspace studies report the following multidisciplinary metrics:

- Greenspace:
    - Quality of greenspace
    - Activities and events organised in greenspaces
    - Number of visitors to greenspace
    - Types of use for greenspace
    - Environmental value of greenspace
    - Social value of greenspace
    - Space to meet, socialise or exercise in the greenspace
- Greenspace access and use:
    - Proximity to greenspace
    - Frequency of use the greenspace

- Socio-cultural context
    - Crime in the local area
    - Health inequalities in the local area

However, the following metrics for studying the sample population are to be encouraged as reporting these across greenspace projects is likely to meet multiple stakeholder priorities:

- Community
    - Community-connectedness
    - Belonging (Neighbourhood belonging)
    - Social inclusion
    - Social trust
    - Neighbourhood satisfaction
- Individual health, wellbeing and environmental identity
    - Mental Health including anxiety, depression, mood and stress
    - Self-reported wellbeing
    - Play
    - Physical activity
    - Relationships with others
    - Environmental awareness/identity
    - Relationship with nature

I recommend that when health metrics are used that these should be clearly defined and use standard and/or internationally recognized definitions, (Rojas-Rueda et al., 2021) suggests using the International Classification of Disease code (ICD) for the health outcome.

Table 2.6. The high-priority metrics (scored 7-9) organised by highest average ranking across stakeholder groups (n=5). Participants also indicated if they used this metric in their work. See the full list of metrics and scores for each stakeholder group in Table 2.9 in the supplementary material.

Rank	Metric	Group	score	SD	Use score (10 max)
1.	Quality of greenspace	Environmental quality, value and connection	8.8	0.6	6
2.	Activities/events organised in greenspaces	Broader measures	8.5	0.7	9
3.	Number of visitors to greenspace	Environmental quality, value and connection	8.5	0.8	7
4.	Space to meet, socialise or exercise	Ecosystem services cultural	8.4	0.8	8
5.	Frequency of use the greenspace	Broader measures	8.2	1.2	8
6.	Community-connectedness	Social	8.2	1.0	6
7.	Social value of green infrastructure	Environmental quality, value and connection	8.2	1.0	4
8.	Belonging (Neighbourhood belonging)	Social	8.1	1.2	6
9.	Social inclusion	Social	8.1	1.1	5
10.	Social trust	Social	8	1.2	5
11.	Relationship with nature	Environmental quality, value and connection	7.9	1.7	5
12.	Proximity to greenspace	Environmental quality, value and connection	7.9	1.4	6
13.	Types of use for greenspace	Broader measures	7.8	1.5	7
14.	Depression	Mental, psychological or emotional	7.8	1.2	6
15.	Play (constructive, functional, symbolic)	Mental, psychological or emotional	7.7	1.3	5
16.	Neighbourhood satisfaction	Quality of life	7.7	2.8	5
17.	Environmental value of green infrastructure	Environmental quality, value and connection	7.7	1.3	3
18.	Health inequalities	Population-level	7.7	1.7	7
19.	Physical activity	Physical and physiological	7.6	1.6	8
20.	Anxiety	Mental, psychological or emotional	7.4	1.4	4
21.	Self-reported wellbeing	Mental, psychological or emotional	7.4	2.7	4
22.	Mood (positive/negative)	Mental, psychological or emotional	7.3	2.7	3
23.	Stress	Mental, psychological or emotional	7.3	2.7	3
24.	Relationships with others	Social	7.3	2.3	6
25.	Crime	Quality of life	7.3	2.9	3
26.	Environmental awareness/identity	Environmental quality, value and connection	7.1	2.5	3
27.	Mental Health Disorders	Mental, psychological or emotional	7	2.4	4

Table 2.7. The high-priority metrics mapped to their associated reviews and studies from Cracknell et al. (2019). Note that nature connection, environmental awareness and economic value of greenspaces were not included in reviews or the associated individual studies.

Stakeholder Ranking	Metric	Reviews
19	Physical activity	Gascon et al., 2017; Houlden et al., 2018; Tillmann et al., 2018; Twohig-Bennett and Jones, 2018
21	Wellbeing	Gascon et al., 2015; Dronavalli and Thompson, 2015; Gascon et al., 2017; Aerts et al., 2018; Houlden et al., 2018; Tillmann et al., 2018; Twohig-Bennett and Jones, 2018; Britton et al., 2020
23	Stress	Gascon et al., 2015; Gascon et al., 2017; Tillmann et al., 2018; Twohig-Bennett and Jones, 2018; Britton et al., 2020
20	Anxiety	Gascon et al., 2015; Gascon et al., 2017; Aerts et al., 2018; Twohig-Bennett and Jones, 2018; Britton et al., 2020
14	Depression	Gascon et al., 2015; Aerts et al., 2018; Tillmann et al., 2018
22	Mood	Gascon et al., 2017; Houlden et al., 2018; Twohig-Bennett and Jones, 2018
24	Relationships	Annerstedt and Währborg, 2011; Twohig-Bennett and Jones, 2018; Britton et al., 2020
15	Play	Twohig-Bennett and Jones, 2018
11	Nature Connection	None
7, 17	Value of greenspaces	None
26	Environmental Awareness	None

Limitations and further research

I recognise the small sample size of this study and encourage further research to repeat the study in other urban greenspace projects that involve multiple stakeholders to build a consensus on useful metrics and methods for urban greenspace studies. The Valuing Nature Project suggested that a broader group of stakeholders could develop a 'traffic light' system for assessing the health metrics that were included in this study in terms of appropriateness, validity, reliability, applicability, responsive and sensitive to change (if applicable), global relevance, timeframe, cross-cultural validity, ability to compare with previous and future research, accessibility & cost, acceptability, linguistically appropriate (age appropriate/English as a second language), ease of use, clarity of tool, time requirements, interpretation of results & analytical capacity and other biases (see Box 3, Cracknell et al., 2019).

Here, I build a stepping-stone to this traffic light system by highlighting consensus across multiple stakeholders for the descriptors and metrics that they believe should be reported across all projects. I also highlighted descriptors and metrics that are used by multiple stakeholders and those that were identified as important but have not been used in their work. I have created a baseline of descriptors and metrics that are relevant across the work of multiple stakeholders and would help standardize the reporting and evidence synthesis across multiple disciplines. The next steps would be to assess the metrics in terms of ease of use or data collection, cost and the quality of data they produce (similar to the evaluation of greenspace quality tools assessed in Knobel et al., 2019). Data sources, tools, comparisons populations and benchmarking could also be highlighted for each metric. For example, for measuring wellbeing, the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and the shorter version (SWEMWB) have mean scores for the general population of the UK that studies can compare their scores to and benchmarked scores to other tools measuring wellbeing (Tennant et al., 2007; Ng Fat et al., 2017; Shah et al., 2021). Due to the limited sample size, I recommend other greenspace projects repeat the ranking exercise with their stakeholders and report their findings and map them to the literature identified in this study as a baseline.

2.5 Conclusion

Urban greenspace is an ambiguous term that has many interpretations. This acts as a barrier to synthesising evidence on urban greenspaces. This could be limiting the resources assigned to urban greenspace management or improvement. As management and costs of greenspaces are predominantly experienced by local governments with increasingly restricted resources (through reduced income and higher inflation) it is important to synthesise across greenspace projects to understand which interventions are effective in promoting benefits for health, ecosystem services and nature to be able to allocate resources appropriately. Therefore, the disparate literature on urban greenspaces needs to be addressed by improving the reporting of what greenspaces are studied and what has been studied in them. As urban greenspace projects often involve multiple disciplines and stakeholders, finding consensus would help when reporting on greenspace projects. I present a baseline set of descriptors that should be reported across urban greenspace projects. The list of high-priority descriptors is interdisciplinary and integrates social and ecological science. I also suggest additional descriptors from the literature that cover ecological and social elements of urban systems that would enable synthesis further. I do not suggest a single definition of urban greenspace as they vary greatly across cultures and contexts but I do recommend that future studies use the baseline set of descriptors of urban greenspace when reporting so that synthesis across studies is easier. I also present a 'suite' of metrics for urban greenspace projects. These cover ecosystem services, cost and disservices, biodiversity and health and wellbeing. Synthesising this list from literature and presenting it in one place can make researchers aware of the breadth and priority of metrics for multiple disciplines. I do not recommend for all metrics to be used in every greenspace study, instead, I highlight that there are metrics that have high priority across multiple stakeholders and high use across multiple stakeholders. I also highlighted gaps in metrics that had consensus across the stakeholders as having high importance but were not used. These included the economic and social value of greenspaces, and this could be explored in further research. I recognise that each study should adapt these descriptors and metrics to their context and scale but if studies can be more detailed and precise in their descriptions then evidence synthesis across greenspace studies can be expedited and enable meta-analysis for urban greenspace interventions. Having more evidence on effective greenspace interventions may leverage resources toward maintaining or improving greenspace or justify the costs incurred through management. Although I reiterate that greenspaces themselves should be seen as enablers of healthy living for communities on a broader scale, as high-quality greenspaces can make an area feel safer, encourage healthy activity, facilitate a stronger sense of community, offer ecosystem services and benefits for nature. Delays in building evidence for causal links or direct mechanisms should not prevent allocating sufficient resources for maintenance as low-quality greenspaces can have negative impacts on people's health and wellbeing and encourage disservices such as anti-social behaviour.

2.6 Supplementary Material

Survey questions:

Consent questions

1. I confirm that I have read and understood the information sheet explaining this research project and that I have had the opportunity to ask questions about this project.
2. I understand that my participation is voluntary. I am free to withdraw at any time during the study without giving any reason with no negative consequences. I can decline to answer any questions.
3. I understand that my responses will be kept securely at the University of Leeds. I understand that my answers will be anonymised, and I give permission for members of the research team to have access to them. I understand that I will not be identifiable in further publications related to this research project.
4. I understand that the anonymized data will be retained for three years after the end of data collection. Within two years of collecting the data will also be deposited in the Natural Environment Research Council data repository and stored for 10 years.
5. My data can be used for future research
6. I am over 18 years old and agree to take part in this research project

7. First name (this is only used to confirm your consent as all responses will be anonymous)
8. Last name (this is only used to confirm your consent as all responses will be anonymous)

Further information

9. Please list the areas or disciplines that you work in (for example 'biodiversity' or 'landscape design' or 'community engagement' or 'healthcare'). Please list as many areas as you feel are relevant to your work related to urban green spaces
10. How many years have you spent studying or working in your field?
11. Are you a member of any environmental organisations or networks (such as wildlife charities or local groups)?
12. Are you a member of any community organisation associated with the use or care of neighbourhood greenspaces?

Table 2.8. List of descriptors and metrics stakeholders were asked to score (1-3: low, 4-6 medium and 7-9 High and 0 if they did not want to score that item). Participants were given the opportunity to add comments and other ideas for each item. Note there were short descriptions for each item, but these have been removed for brevity here. An * indicates where items were added by authors from experience working on urban greenspace projects and were additional to those identified from the literature.

				Please score each row for the following criteria:		
			Outcomes	**1. It is important to include as part of greenspace project evaluation or research**	**2. Have you used this measure in your work on urban greenspaces?**	Optional Comments (such as why you gave it that score or if there is anything else to be considered when assessing this metric).
			(Please note that I am working at an outcome level rather than scoring specific tools or methods to measure each outcome)	Low: 1 to High: 9 or 0 if you do not wish to score that measure	Put '1' for yes or '0' for no	
How to describe urban greenspaces when reporting in studies and projects (13)	Allow for repetition from the *below* measures. The aim is to set a standard for how we should report on our greenspace study sites (this may include some of the above measures). Note this is not to generate a single definition of greenspaces but to create a set of baseline descriptions to help with understanding the different greenspaces	1	Biodiversity: habitat (number and extent)			
		2	Biodiversity: species abundance			
		3	Biodiversity: species richness			
		4	Connectivity or fragmentation between greenspaces			
		5	Gradient of urbanisation			
		6	Greenspace Landscape			
		7	Management type			
		8	Number of people with access to the greenspace (out of total population)			
		9	Ownership			
		10	Qualitative description of vegetation mix			
		11	Size of greenspace and blue space (area)			
		12	Type of greenspace			
		13	User quality			

	studied and enable easier knowledge exchange (source: Taylor & Hochuli 2017).	14	OTHER			
Broader measures for urban greenspaces (10):		15	*Activities and events organised in greenspaces			
		16	*Area managed for wildlife			
		17	*Employment associated with greenspace			
		18	*Frequency of use the greenspace			
		19	*Length of use of greenspace			
		20	*Naturalness of greenspace (perceived)			
		21	*Patterns of use			
		22	*Social media posts about the greenspace			
		23	*Surrounding land cover			
		24	*Types of use for greenspace			
		25	*surrounding greenspaces at a given scale (number, size, connectivity)			
		26	OTHER			
Ecosystem Services or Nature's Contribution to People (38) (source: CICES Version 5.1	**Provisioning (Biotic): Biomass**	27	Cultivated terrestrial plants for nutrition, materials or energy			
		28	Cultivated aquatic plants for nutrition, materials or energy			
		29	Reared animals for nutrition, materials or energy			
		30	Reared aquatic animals for nutrition, materials or energy			
		31	Wild plants (terrestrial and aquatic) for nutrition, materials or energy			
		32	Wild animals (terrestrial and aquatic) for nutrition, materials or energy			
	Provisioning (Biotic): Genetic material from all biota	33	Genetic material from plants, algae or fungi			
		34	Genetic material from animals			
		35	Provisioning (Biotic): Other types of provisioning service from biotic sources			

	Provisioning (Abiotic): Water	36	Surface water used for nutrition, materials or energy			
		37	Ground water for used for nutrition, materials or energy			
	Regulation & Maintenance (Biotic): Transformation of biochemical or physical inputs to ecosystems	38	Mediation of wastes or toxic substances of anthropogenic origin by living processes (such as pollution)			
		39	Mediation of nuisances of anthropogenic origin (such as smell)			
		40	Regulation of flows and extreme events			
		41	Lifecycle maintenance, habitat and gene pool protection			
		42	Pest control			
		43	Regulation of soil quality			
		44	Water conditions			
		45	Atmospheric composition and conditions			
		46	*Carbon storage			
	Cultural (Biotic): Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	47	Physical and experiential interactions with natural environment (active, passive, immersive, observational)			
		48	Scientific or traditional ecological knowledge: intellectual and representative interactions with natural environment			
		49	Education and training: Intellectual and representative interactions with natural environment			
		50	Culture or heritage: Intellectual and representative interactions with natural environment			
		51	Aesthetic experiences: Intellectual and representative interactions with natural environment			
	Cultural (Biotic): Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	52	Spiritual, symbolic and other interactions with natural environment			
		53	Other biotic characteristics that have a non-use value			
		54	Other characteristics of living systems that have cultural significance			
		55	*Economic benefits			
	***Cultural (abiotic):**	56	*Space to meet, socialise or exercise			

		57	*Varying topography			
		58	OTHER			
Ecosystem Disservices (33) (source: Lyytimaki et al.2008 (adapted from Petersen et al. 2007, Potgieter et al. 2017, Von Döhren & Haase 2015, Escobedo et al . 2011)	**Aesthetic issues**	59	Animals searching for food in litter bins (presence, abundance, species richness)			
		60	Areas of unpleasant untidy areas of vegetation			
		61	Sounds, smells and behaviour of plants and animals perceived as negative by people			
		62	Views blocked by plants			
		63	*Water features that are poorly managed, high biodiversity can be seen as unpleasant			
	Economic issues	64	Costs are caused by attempts to remove unwanted species			
		65	Damage to structures			
		66	Harmful species (can damage those species that are cared for and thus cause economic loss)			
		67	Maintaining costs (such as planting and removing)			
		68	Reduction in property value			
	Environmental issues	69	Alteration of soil fertility and nutrient flow			
		70	Decrease in water quality/quantity			
		71	Displacement of native or endemic species			
		72	Introduction of non-native and or invasive species			
		73	Reducing species diversity			
	Health and safety issues or unintended consequences	74	Allergies or intoxication			
		75	Areas with natural features that are perceived as unsafe, especially in night-time			
		76	Certain animal species can be vectors of diseases			
		77	*Plants and animals are perceived as dangerous			
		78	Reduced air quality			
		79	*Water features can be seen as unsafe			
		80	Wild or semi-wild animals in larger park areas can cause fear, anxiety and inconvenience.			
	Issues in use	81	Presence of protected species restricting use of the area			

		82	*Uneven ground or muddy areas			
	Mobility issues	83	Large green or blue areas can obstruct fast and convenient transportation			
		84	Visibility issues from vegetation			
		85	Green waste, leaf litter, debris, falling tree, branches			
		86	OTHER			
Biodiversity and nature (17)	**Essential Biodiversity Variables** (source: Pereira et al. 2013)	87	*Biodiversity likely to be experienced			
		88	Community composition (such as the mix of species and or the interactions between them)			
		89	Ecosystem composition by functional type			
		90	Ecosystem functions (Net primary productivity, disturbance regime, nutrient retention)			
		91	Extent of habitats			
		92	Habitat connectivity and fragmentation			
		93	Habitat structure			
		94	*Invisible biodiversity			
		95	*Perceived biodiversity			
		96	*Presence of protected or flagship species			
		97	*Abundance of functional groups			
		98	Species abundance			
		99	Genetics			
		100	Survival rate			
		101	Traits (such as phenology or morphology, movement and dispersal ability)			
		102	Species richness			
		103	OTHER			
Health and wellbeing (source 'Demystifying Health Metrics' Valuing Nature Project)	**Physical and physiological (35)**	104	Allergies (prevalence and/or severity)			
		105	Antibodies (levels/presence)			
		106	Asthma			
		107	Brain activity			
		108	Breathing			

		109	Blood pressure (Systolic BP/Diastolic BP, hypertension, arterial stiffness)			
		110	Body awareness			
		111	Baby's health in first 5 mins			
		112	Birth weight and gestational age			
		113	Baby head circumference at birth			
		114	Child development			
		115	Cancer (such as risk, cases, coping)			
		116	Cholesterol			
		117	Chronic obstructive pulmonary disease (COPD)			
		118	Dementia			
		119	Diabetes			
		120	Dopamine			
		121	Falls			
		122	Fine motor ability			
		123	General health			
		124	Heart health			
		125	Hospitalisation			
		126	Human parasite abundance			
		127	Infection rates			
		128	Life expectancy			
		129	Microbiota (such as skin or nasal microbes)			
		130	Mobility			
		131	Nutrition			
		132	Obesity			
		133	Pain/discomfort			
		134	Physical activity			
		135	Physical fitness			
		136	Respiratory disease			

		137	Sleep (amount, quality)			
		138	OTHER			
	Mental, psychological or emotional (47)	139	Attention deficit hyperactivity disorder (ADHD)			
		140	Anxiety			
		141	Craving (or either addictive or non-addictive substances)			
		142	Depression (cases, symptoms, perceived, coping)			
		143	Mental Health Disorders			
		144	Medication			
		145	Psychological distress			
		146	Post-traumatic stress disorder (PTSD)			
		147	Vitality			
		148	Resilience			
		149	Mindfulness			
		150	Mood (positive/negative)			
		151	Emotions (enjoyment, happiness, loneliness)			
		152	Stress (perceived, parenting, attentional fatigue)			
		153	Restorativeness (including attention restoration theory)			
		154	Self-reported wellbeing			
		155	Spiritual well-being			
		156	Eudaimonic well-being			
		157	Self-awareness			
		158	Self-esteem or self-worth			
		159	Self-efficacy			
		160	Aspirations			
		161	Attention (on surrounding environment, deficit, engagement, inattentiveness)			
		162	Cognitive (flexibility, impairment, performance)			
		163	Learning			
		164	Memory (verbal, visual, superior working memory)			

		165	Reaction time			
		166	Processing and Psychomotor speed			
		167	Aggression			
		168	Agitation			
		169	Arousal			
		170	Confidence			
		171	Creativity			
		172	Decision making			
		173	Empathy			
		174	Feelings about behaving in healthy ways			
		175	Habitual behaviours			
		176	Impulses			
		177	Motivation			
		178	Play (constructive, functional, symbolic)			
		179	Problematic behaviours			
		180	Punishment and reward sensitivity			
		181	Risk taking			
		182	Sensation seeking			
		183	OTHER			
	Social (5)	184	Belonging (Neighbourhood belonging)			
		185	Community-connectedness			
		186	Relationships with others (partners, children, family, friends, parent and baby, social skills, social capitol, family functioning, risk of abuse)			
		187	Social inclusion			
		188	Social trust			
		189	OTHER			
	Quality of life (6)	190	Achieving in life/Personal development			
		191	Crime			
		192	Life satisfaction			

		193	Neighbourhood satisfaction			
		194	Quality Adjusted Life Years (QALYs)			
		195	Standard of living/Material wellbeing			
		196	OTHER			
	Environmental quality, value and connection (9)	197	Relationship with nature (connection to, affinity to, nature relatedness, inclusion of self in nature)			
		198	Environmental awareness/identity			
		199	Environmental value of green infrastructure			
		200	Number of visitors to greenspace			
		201	Social value of green infrastructure			
		202	Social return on investment for public health interventions			
		203	Proximity to greenspace			
		204	Quality of greenspace			
		205	Economic value of green infrastructure.			
		206	OTHER			
	Population-level (9)	207	Births			
		208	Deaths			
		209	Health inequalities			
		210	Heat-related excess mortality (in the elderly)			
		211	Motor vehicle fatalities			
		212	Number of chronic conditions			
		213	Number of years lost due to ill-health, disability or early death			
		214	Prevalence of asthma			
		215	Prevalence of osteoporosis			
		216	OTHER			

Table 2.9. The metrics organised by highest average ranking across stakeholder groups (n=10). Participants also indicated if they used this metric in their work. The average scores for stakeholder groups are also displayed. Note that for local government and community member stakeholders, this is not an average but a raw score from a single participant.

Rank	Measure	Score	SD	Use score (10 max)	Researcher	Delivery partner	Community worker	Community member	Local government
1.	Quality of greenspace	8.8	0.6	6	9.0	9.0	8.3	9.0	9.0
2.	Number of visitors to greenspace	8.5	0.8	7	9.0	8.7	8.2	7.0	9.0
3.	*Activities and events organised in greenspaces	8.5	0.7	9	8.8	8.6	8.2	9.0	8.0
4.	*Space to meet, socialise or exercise	8.4	0.8	8	8.3	8.8	8.3	9.0	8.0
5.	Social value of green infrastructure	8.2	1.0	4	8.0	8.3	8.1	8.0	9.0
6.	*Frequency of use the greenspace	8.2	1.2	8	9.0	8.7	7.9	6.0	8.0
7.	Community-connectedness	8.2	1.0	6	8.5	8.5	7.8	9.0	7.0
8.	Belonging (Neighbourhood belonging)	8.1	1.2	6	8.0	8.3	7.8	9.0	8.0
9.	Social inclusion	8.1	1.1	5	8.5	8.2	7.7	9.0	7.0
10.	Social trust	8	1.2	5	8.3	8.1	7.7	9.0	7.0
11.	Relationship with nature (connection to, affinity to, nature relatedness, inclusion of self in nature)	7.9	1.7	5	7.8	8.3	7.1	9.0	9.0
12.	Proximity to greenspace	7.9	1.4	6	8.0	8.3	8.1	7.0	7.0
13.	*Types of use for greenspace	7.8	1.5	7	7.0	8.3	8.1	8.0	8.0
14.	Depression (cases, symptoms, perceived, coping)	7.8	1.2	6	8.3	7.8	7.6	9.0	6.0
15.	Environmental value of green infrastructure	7.7	1.3	3	7.8	6.9	7.3	9.0	9.0
16.	Neighbourhood satisfaction	7.7	2.8	5	8.8	5.9	7.3	9.0	8.0
17.	Play (constructive, functional, symbolic)	7.7	1.3	5	6.8	8.3	8.1	9.0	7.0
18.	Health inequalities	7.7	1.7	7	7.8	8.3	7.8	9.0	5.0
19.	Physical activity	7.6	1.6	8	8.3	7.8	7.6	9.0	4.0
20.	Self-reported wellbeing	7.4	2.7	4	8.5	7.5	5.5	9.0	8.0
21.	Anxiety	7.4	1.4	4	7.3	7.4	7.5	9.0	6.0
22.	Crime	7.3	2.9	3	8.0	5.7	6.9	9.0	8.0
23.	Stress (perceived, parenting, attentional fatigue)	7.3	2.7	3	7.8	7.9	5.6	9.0	8.0
24.	Mood (positive/negative)	7.3	2.7	3	8.0	7.7	5.6	9.0	8.0
25.	Relationships with others (partners, children, family, friends, parent and baby, social skills, social capitol, family functioning, risk of abuse)	7.3	2.3	6	6.5	7.8	7.6	9.0	6.0
26.	Environmental awareness/identity	7.1	2.5	3	6.0	6.7	7.2	9.0	9.0
27.	Mental Health Disorders	7	2.4	4	6.3	7.1	7.4	9.0	6.0
28.	Economic value of green infrastructure.	6.8	2.5	1	7.3	5.1	6.0	9.0	9.0
29.	Social return on investment for public health interventions	6.8	2.6	2	6.8	4.9	7.0	8.0	9.0
30.	*Area managed for wildlife	6.8	2.4	6	5.3	7.4	8.1	5.0	8.0
31.	*Water features can be seen as unsafe	6.7	3.0	5	4.0	7.0	7.7	9.0	9.0
32.	Life satisfaction	6.7	2.9	1	7.5	4.2	6.4	9.0	8.0

33.	Reduced air quality	6.7	3.1	6	4.3	7.4	7.8	9.0	7.0
34.	Problematic behaviours	6.7	2.3	3	5.3	6.8	7.3	9.0	7.0
35.	Areas of unpleasant untidy areas of vegetation	6.7	1.9	5	5.8	6.6	6.9	9.0	7.0
36.	General health	6.7	2.3	5	7.5	5.5	6.8	9.0	4.0
37.	Restorativeness (including attention restoration theory)	6.6	3.6	3	7.8	5.6	4.9	9.0	8.0
38.	*Patterns of use	6.6	2.4	7	7.0	7.0	7.7	1.0	7.0
39.	Quality Adjusted Life Years (QALYs)	6.5	3.6	3	8.0	5.7	4.9	9.0	6.0
40.	Aesthetic experiences: Intellectual and representative interactions with natural environment	6.5	2.2	5	5.5	7.5	7.5	6.0	5.0
41.	*Length of use of greenspace	6.4	1.4	4	5.8	6.3	6.1	8.0	8.0
42.	*Employment associated with greenspace	6.4	2.0	4	6.8	6.6	6.2	4.0	8.0
43.	Areas with natural features that are perceived as unsafe, especially in night-time	6.4	2.0	5	5.0	6.7	7.9	5.0	7.0
44.	Standard of living/Material wellbeing	6.3	3.1	4	5.8	4.9	6.3	9.0	8.0
45.	Sounds, smells and behaviour of plants and animals perceived as negative by people	6.3	1.8	4	5.8	6.6	5.9	8.0	7.0
46.	*Water features that are poorly managed, high biodiversity can be seen as unpleasant	6.3	2.2	4	5.8	7.6	5.5	7.0	7.0
47.	Cognitive (flexibility, impairment, performance)	6.3	2.8	2	6.5	6.5	5.2	9.0	6.0
48.	Culture or heritage: Intellectual and representative interactions with natural environment	6.3	2.7	4	4.8	7.3	7.4	7.0	5.0
49.	Mindfulness	6.2	3.3	2	5.8	4.3	6.1	9.0	9.0
50.	*Presence of protected or flagship species	6.2	2.9	4	4.3	6.8	6.6	9.0	7.0
51.	*Naturalness of greenspace (perceived)	6.2	2.0	4	5.0	6.0	7.0	7.0	7.0
52.	Extent of habitats	6.2	1.6	4	5.8	6.3	6.8	5.0	7.0
53.	Mediation of nuisances of anthropogenic origin (such as smell)	6.2	2.3	2	4.8	7.3	7.8	5.0	5.0
54.	Resilience	6.1	3.0	1	7.3	6.4	5.1	9.0	2.0
55.	Risk taking	6	3.4	3	4.5	4.5	6.8	9.0	8.0
56.	Emotions (enjoyment, happiness, loneliness)	5.9	3.4	2	6.5	4.5	4.5	9.0	8.0
57.	*Varying topography	5.9	2.5	5	4.0	6.0	7.3	5.0	8.0
58.	*Social media posts about the greenspace	5.9	2.2	4	4.5	5.5	6.8	7.0	7.0
59.	*Perceived biodiversity	5.9	2.0	2	5.5	6.2	6.4	4.0	7.0
60.	Physical and experiential interactions with natural environment (active, passive, immersive, observational)	5.9	3.3	4	4.8	7.3	5.4	9.0	5.0
61.	*Abundance of functional groups	5.8	2.8	3	4.0	5.7	6.6	8.0	7.0
62.	*surrounding greenspaces at a given scale (number, size, connectivity)	5.8	2.8	5	4.8	6.6	7.2	2.0	7.0
63.	Wild or semi-wild animals in larger park areas can cause fear, anxiety and inconvenience.	5.8	2.8	2	4.0	6.0	6.3	9.0	6.0
64.	Maintaining costs (such as planting and removing)	5.8	2.1	5	6.0	7.0	5.7	3.0	6.0
65.	Prevalence of asthma	5.8	2.7	3	6.3	4.4	5.5	9.0	5.0
66.	Scientific or traditional ecological knowledge: intellectual and representative interactions with natural environment	5.8	2.7	3	4.0	6.0	7.3	7.0	5.0
67.	Obesity	5.8	3.1	4	7.0	3.0	6.0	9.0	4.0

68.	Spiritual, symbolic and other interactions with natural environment	5.8	2.7	1	5.0	6.0	6.3	8.0	4.0
69.	Ecosystem composition by functional type	5.7	1.8	3	4.5	6.5	6.2	5.0	7.0
70.	Decrease in water quality/quantity	5.7	2.1	2	3.8	6.6	6.9	6.0	6.0
71.	Pest control	5.7	2.4	3	4.0	6.7	6.6	7.0	5.0
72.	Asthma	5.7	3.7	3	6.5	5.2	4.7	9.0	4.0
73.	Memory (verbal, visual, superior working memory)	5.6	3.4	2	5.5	2.8	5.9	9.0	7.0
74.	Animals searching for food in litter bins (presence, abundance, species richness)	5.6	2.5	4	3.8	5.9	6.0	9.0	6.0
75.	Attention (on surrounding environment, deficit, engagement, inattentiveness)	5.6	3.8	2	6.5	4.2	4.4	9.0	6.0
76.	*Uneven ground or muddy areas	5.6	2.5	4	4.8	5.6	6.2	6.0	6.0
77.	Feelings about behaving in healthy ways	5.6	3.3	2	4.5	6.5	5.2	9.0	5.0
78.	Education and training: Intellectual and representative interactions with natural environment	5.6	3.3	4	4.8	6.6	5.2	8.0	5.0
79.	Blood pressure (Systolic BP/Diastolic BP, hypertension, arterial stiffness)	5.6	3.5	2	6.8	4.6	4.5	9.0	4.0
80.	*Economic benefits	5.5	3.0	1	5.0	4.3	5.1	9.0	7.0
81.	Species richness	5.5	2.7	5	4.5	4.5	6.2	7.0	7.0
82.	*Plants and animals are perceived as dangerous	5.5	2.6	2	3.0	5.3	6.8	9.0	6.0
83.	Learning	5.5	3.8	2	5.5	4.8	4.6	9.0	6.0
84.	Certain animal species can be vectors of diseases	5.5	2.5	1	3.5	5.2	6.7	9.0	5.0
85.	Number of years lost due to ill-health, disability or early death	5.5	2.3	3	5.8	4.3	5.1	9.0	5.0
86.	Lifecycle maintenance, habitat and gene pool protection	5.5	2.5	3	3.3	6.8	6.6	7.0	5.0
87.	Regulation of flows and extreme events	5.5	2.9	3	3.5	6.8	6.6	6.0	5.0
88.	Allergies or intoxication	5.5	2.7	2	3.3	5.8	6.9	9.0	4.0
89.	Spiritual well-being	5.4	3.9	1	6.3	3.1	4.0	9.0	8.0
90.	Community composition (such as the mix of species and or the interactions between them)	5.4	1.5	3	4.3	6.1	5.7	5.0	7.0
91.	Displacement of native or endemic species	5.4	2.5	2	3.5	6.2	7.1	5.0	5.0
92.	Post-traumatic stress disorder (PTSD)	5.4	3.4	1	5.8	5.9	4.6	9.0	2.0
93.	Presence of protected species restricting use of the area	5.3	3.5	3	3.8	4.3	5.1	9.0	9.0
94.	Self-awareness	5.3	3.7	1	5.5	3.5	4.2	9.0	8.0
95.	Harmful species (can damage those species that are cared for and thus cause economic loss)	5.3	2.3	3	4.3	6.1	5.7	5.0	6.0
96.	Births	5.3	3.1	3	3.5	4.2	6.7	9.0	5.0
97.	Confidence	5.3	3.2	3	5.0	3.3	5.8	9.0	5.0
98.	Water conditions	5.3	1.9	3	3.8	6.6	6.2	5.0	5.0
99.	Respiratory disease	5.3	3.5	2	5.8	2.6	5.9	9.0	4.0
100.	Child development	5.3	3.4	3	5.3	5.1	4.7	9.0	4.0
101.	Allergies (prevalence and/or severity)	5.3	3.5	3	6.3	4.1	4.4	9.0	4.0
102.	*Biodiversity likely to be experienced	5.2	2.5	5	3.3	5.8	6.3	5.0	7.0
103.	*Invisible biodiversity	5.2	2.7	2	4.0	6.0	5.7	4.0	7.0
104.	Damage to structures	5.2	2.4	3	4.3	6.4	5.5	4.0	6.0

105.	*Surrounding land cover	5.2	2.0	4	4.5	5.8	5.9	3.0	6.0
106.	*Carbon storage	5.2	2.8	3	4.5	7.2	6.1	1.0	5.0
107.	Fine motor ability	5.2	3.5	1	5.5	4.5	4.5	9.0	4.0
108.	Psychological distress	5.2	3.3	1	5.0	5.7	4.9	9.0	2.0
109.	Eudaimonic well-being	5.1	3.7	2	5.8	2.9	3.6	9.0	8.0
110.	Habitat connectivity and fragmentation	5.1	2.4	4	3.0	5.3	6.4	5.0	7.0
111.	Species abundance	5.1	2.1	5	4.0	5.3	5.4	5.0	7.0
112.	Self-esteem or self-worth	5.1	3.5	1	5.5	3.5	4.2	9.0	6.0
113.	Costs are caused by attempts to remove unwanted species	5.1	2.2	3	4.3	5.8	5.3	5.0	6.0
114.	Physical fitness	5.1	3.7	2	5.8	3.9	4.3	9.0	4.0
115.	Aspirations	5.0	3.7	1	5.0	3.7	4.2	9.0	6.0
116.	Regulation of soil quality	5.0	2.3	2	3.0	6.3	6.1	5.0	5.0
117.	Introduction of non-native and or invasive species	5.0	3.1	3	3.8	6.3	6.8	1.0	5.0
118.	Birth weight and gestational age	5.0	3.4	3	4.8	4.6	4.5	9.0	4.0
119.	Breathing	5.0	3.8	1	5.3	4.1	4.4	9.0	4.0
120.	Life expectancy	4.9	3.3	2	4.8	2.3	5.8	9.0	4.0
121.	Brain activity	4.9	3.9	1	5.0	4.0	4.3	9.0	4.0
122.	Sleep (amount, quality)	4.9	3.8	1	6.3	2.8	3.9	9.0	4.0
123.	Visibility issues from vegetation	4.8	2.6	4	4.0	5.3	5.4	1.0	8.0
124.	Habitat structure	4.8	2.3	4	2.8	5.3	6.1	4.0	7.0
125.	Achieving in life/Personal development	4.8	3.0	2	4.3	3.1	4.7	9.0	6.0
126.	Sensation seeking	4.8	3.7	1	4.3	3.8	4.3	9.0	6.0
127.	Motivation	4.8	3.4	1	5.0	3.3	4.1	9.0	5.0
128.	Reducing species diversity	4.8	2.8	2	3.5	5.8	6.6	1.0	5.0
129.	Ecosystem functions (Net primary productivity, disturbance regime, nutrient retention)	4.7	2.2	2	4.3	5.8	3.6	5.0	7.0
130.	Self-efficacy	4.7	3.7	1	5.0	2.7	3.9	9.0	6.0
131.	Number of chronic conditions	4.7	2.9	1	5.3	2.1	4.4	9.0	5.0
132.	Creativity	4.7	3.4	2	4.8	3.3	4.1	9.0	5.0
133.	Punishment and reward sensitivity	4.7	3.5	1	4.8	3.3	4.1	9.0	5.0
134.	Mobility	4.7	3.1	2	4.3	2.1	5.7	9.0	4.0
135.	Body awareness	4.7	3.8	1	5.0	3.3	4.1	9.0	4.0
136.	Heart health	4.7	3.8	1	5.8	2.6	3.9	9.0	4.0
137.	Pain/discomfort	4.7	3.8	1	5.8	2.6	3.9	9.0	4.0
138.	Antibodies (levels/presence)	4.7	3.6	1	5.3	3.8	3.6	9.0	4.0
139.	Views blocked by plants	4.6	2.9	4	4.3	6.4	4.1	1.0	7.0
140.	Motor vehicle fatalities	4.6	3.2	2	4.0	1.7	5.6	9.0	5.0
141.	Habitual behaviours	4.6	3.9	2	3.8	3.9	4.3	9.0	5.0
142.	Decision making	4.6	3.5	2	4.5	3.2	4.1	9.0	5.0
143.	Empathy	4.6	3.5	2	4.5	3.2	4.1	9.0	5.0
144.	Reaction time	4.6	3.6	1	5.0	2.7	3.9	9.0	5.0
145.	Dopamine	4.6	3.8	1	5.5	2.5	3.8	9.0	4.0
146.	Hospitalisation	4.6	3.8	1	5.5	2.5	3.8	9.0	4.0

147.	Deaths	4.5	2.8	1	4.5	1.8	4.6	9.0	5.0
148.	Processing and Psychomotor speed	4.5	3.6	1	4.8	2.6	3.9	9.0	5.0
149.	Aggression	4.5	3.6	1	5.3	2.1	3.7	9.0	5.0
150.	Mediation of wastes or toxic substances of anthropogenic origin by living processes (such as pollution)	4.5	3.3	3	2.8	3.9	7.0	3.0	5.0
151.	Diabetes	4.5	3.6	1	5.8	2.6	3.2	9.0	4.0
152.	Vitality	4.5	3.4	1	5.0	3.3	4.1	9.0	2.0
153.	Prevalence of osteoporosis	4.4	2.8	1	4.5	1.8	4.3	9.0	5.0
154.	Arousal	4.4	3.8	1	5.0	2.0	3.7	9.0	5.0
155.	Infection rates	4.4	3.7	1	5.3	2.4	3.5	9.0	4.0
156.	Human parasite abundance	4.4	3.6	1	5.5	2.5	3.2	9.0	4.0
157.	Dementia	4.4	3.6	1	5.8	2.6	2.9	9.0	4.0
158.	Heat-related excess mortality (in the elderly)	4.3	2.8	2	4.5	1.8	3.9	9.0	5.0
159.	Agitation	4.3	3.7	1	4.8	1.9	3.6	9.0	5.0
160.	Cholesterol	4.3	3.7	1	5.3	2.4	3.1	9.0	4.0
161.	Genetics	4.2	2.0	1	2.5	4.8	4.3	5.0	7.0
162.	Traits (such as phenology or morphology, movement and dispersal ability)	4.2	2.0	1	2.8	4.9	4.0	5.0	7.0
163.	Impulses	4.2	3.7	1	4.5	1.8	3.6	9.0	5.0
164.	Attention deficit hyperactivity disorder (ADHD)	4.2	3.9	1	4.8	1.6	3.5	9.0	5.0
165.	Baby head circumference at birth	4.2	3.6	2	4.5	2.2	3.7	9.0	4.0
166.	Cancer (such as risk, cases, coping)	4.2	3.7	1	5.0	2.3	3.1	9.0	4.0
167.	Nutrition	4.2	3.7	1	5.0	2.3	3.1	9.0	4.0
168.	Chronic obstructive pulmonary disease (COPD)	4.2	3.6	1	5.3	2.4	2.8	9.0	4.0
169.	Medication	4.2	3.6	2	4.5	3.2	3.7	9.0	2.0
170.	Survival rate	4.1	2.1	1	2.5	4.8	3.9	5.0	7.0
171.	Reduction in property value	4.1	2.2	1	4.0	5.0	4.0	1.0	6.0
172.	Alteration of soil fertility and nutrient flow	4.1	2.3	2	3.0	3.0	5.0	6.0	5.0
173.	Atmospheric composition and conditions	4.1	2.9	3	3.8	4.3	4.8	2.0	5.0
174.	Falls	4.1	3.5	1	5.5	2.5	2.2	9.0	4.0
175.	Cultivated terrestrial plants for nutrition, materials or energy	3.9	2.8	2	4.0	1.7	4.6	3.0	7.0
176.	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	3.9	2.8	3	4.0	1.7	4.6	3.0	7.0
177.	Baby's health in first 5 mins	3.9	3.5	1	3.8	1.9	3.6	9.0	4.0
178.	Large green or blue areas can obstruct fast and convenient transportation	3.8	2.3	3	3.3	4.1	3.7	1.0	8.0
179.	Green waste, leaf litter, debris, falling tree, branches	3.8	2.6	3	3.5	3.8	3.6	1.0	8.0
180.	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	3.8	2.9	2	4.0	1.7	4.2	3.0	7.0
181.	Cultivated aquatic plants for nutrition, materials or energy	3.7	2.7	1	4.0	1.7	3.9	3.0	7.0
182.	Other biotic characteristics that have a non-use value	3.7	3.1	1	3.5	3.2	3.7	5.0	4.0
183.	Craving (or either addictive or non-addictive substances)	3.6	3.5	1	4.8	1.6	2.2	9.0	3.0
184.	Reared animals for nutrition, materials or energy	3.5	2.5	1	4.0	1.7	3.6	3.0	6.0
185.	Reared aquatic animals for nutrition, materials or energy	3.5	2.5	1	4.0	1.7	3.6	3.0	6.0
186.	Microbiota (such as skin or nasal microbes)	3.5	3.5	1	4.3	2.1	3.0	9.0	0.0

187.	Ground water for used for nutrition, materials or energy	3.3	1.9	2	2.3	2.6	4.5	1.0	6.0
188.	Surface water used for nutrition, materials or energy	3.2	1.9	1	2.3	2.6	4.2	1.0	6.0
189.	Genetic material from plants, algae or fungi	2.9	1.9	1	2.5	3.2	2.4	2.0	6.0
190.	Genetic material from animals	2.9	1.9	1	2.5	3.2	2.4	2.0	6.0
191.	Other characteristics of living systems that have cultural significance	2.4	3.5	1	2.8	0.9	3.3	4.0	0.0
192.	Provisioning (Biotic): Other types of provisioning service from biotic sources	1.1	2.2	1	0.5	0.2	2.4	2.0	0.0

Table 2.10. Summary of the descriptors identified in the literature review and elements that were not included in this study.

Study	Descriptions
Taylor and Hochuli, 2017	Tree cover
Hunter and Luck, 2015	Socio-cultural, Temporal land use change, Designation
Mcintyre et al., 2000	Economic characteristics (e.g., average housing value), Population density, Study scale (grain and extent, traffic frequency, Historical, current, and adjacent land-use types, Age since conversion from indigenous habitat, Housing type and density and Road type and density)
Royer et al., 2023	Urban agriculture as part of the greenspace landscape (location, production and food system)
Jalkanen and Vierikko, 2022	Biodiversity aspects that include: habitat specialist species, biomass, evenness, uniqueness, regional representativeness and sensitivity
Robinson et al., 2022	Tree cover, greenness (NDVI) and accessibility (1 km buffer)
Niedźwiecka-Filipiak et al., 2022	Greenspace is everything outside what the authors define as a core village (built-up areas)
Koh et al., 2022	Cultural services as part of greenspace function

Matsler et al., 2021	Planning, ecology and water aspects of a green infrastructure definition
Castellar et al., 2021	Biodiversity, cultural/social services, ecosystem services (water, flood management and soil)
Rojas-Rueda et al., 2021	Green density or proximity, green presence, green spaces index (sustainable development index), environmental index (that included the presence of vegetation, agriculture, forestry, and grassland), neighbourhood environment index (that included hectares of parks per 1000 residents), and green space visit.
Klaus and Kiehl, 2021	Specific urban reference systems are presented to explore ecological restoration in urban greenspaces to support desired species composition and/or high levels of desired ecosystem functions and services
Delgado-Capel and Cariñanos, 2020	Used land cover (Corine Land Cover Classes (Level 3), occupied by agriculture, with significant areas of natural vegetation, agro-forestry areas, broad-leaved forest, coniferous forest, mixed forest, natural grasslands, moors and heathland, sclerophyllous vegetation, transitional woodland-shrub, beaches, dunes, sands) and public access (100 m 300 m and 500 m buffer) and spatial distribution (linear or patch).
Seiwert and Rößler, 2020	Elements of green infrastructure network-character, multi-functionality as well as the spatial provisioning of ecosystem services
Mu and Li, 2020	The authors note the range of definitions in literature often referred to as generic 'green space' and includes almost any land type that has not been built on.
Im, 2019	This uses a framework for green infrastructure based on type of roads or transport the green feature is situated. The authors offer a framework for describing green streets.
Knobel et al., 2019	Surroundings, Accessibility, Facilities, Amenities, Aesthetics and attractions, Incivilities, Safety, Usage/activities, land covers, park policies, Animal biodiversity, Plant biodiversity
Lai et al., 2019	Green spaces, as we have defined them, include many different habitats, ranging from forests, conserved areas, parks, gardens, yards, and remnant patches of native vegetation to patches of vegetation within assemblages of modern or historically built environments.
Soltanifard and Jafari, 2019	Biodiversity should be included in greenspace definition

Pregitzer et al., 2019	Authors recommend defining tree features in more detail. Current definitions of the urban forest include all trees growing in the urban environment. However, different types require different management (street trees vs forest areas).
Voghera and Giudice, 2019	Definitions of human systems are: an indicator of soil artificialization, an indicator of transport networks, an indicator of demography, density of energetic network, and planning. Green infrastructure was defined by the ecosystem services provided including climate change mitigation and adaptation, connectivity, access, biodiversity and cultural services.
Corley et al., 2018	Greenspace quality should not be assumed based on size. Quality measures should include safety, access, amenities, social inclusion, aesthetics, and ecological vitality.
Klompmaker et al., 2018	Defined greenspace based on the Normalized Difference Vegetation Index (NDVI) or land-use database. Also measured access (distance to the nearest park entrance)
Farinha-Marques et al., 2017	Authors offer a method for recording urban biodiversity (Urban Habitats Biodiversity Assessment)
Jerome et al., 2017	Authors provide a framework to explore urban greenspace community engagement. They offer four groups in their typology: 'Formal Group (active), Formal Group (inactive), Formal Project and Informal Group.
Perchoux et al., 2016	The authors compare measures/definitions of greenspace access. They include buffer and network methods and an individual's perceived activity area.
Amarawickrama et al., 2015	Authors describe dimensions of urban sprawl: density, concentration, proximity to services, automobile dependency, and extent of vegetation cover
Rupprecht and Byrne, 2014	Typology of greenspaces: Street verges Roadside verges, roundabouts, tree rings, informal trails and footpaths, vacant lots, microsites and gaps between walls, railway tracks, waterside tracks, brownfield, structural features (green walls or roofs), power lines and rights of way. Their definition and description explicitly excludes remnant vegetation, parks, ornamental plantings (e.g. Flowerbeds), gardens, secondary-growth urban forests and agricultural areas (fields, rice paddies, etc.)
Yao et al., 2014	This paper proposes a metric of effective green equivalent (EGE), which is defined as the area of green space multiplied by corrected coefficients of quality and accessibility.
La Rosa and Privitera, 2013	Greenspace is defined as Non-urbanized areas (NUAs) - outdoor places with significant amounts of vegetation.

Gupta et al., 2012	The authors propose the Urban Neighbourhood Green Index include green infrastructure, proximity to green, built-up density and height of structures.
Feest et al., 2009	Measuring biodiversity quality in an urban greenspace includes: Species Richness, Simpson's Index, Population Density, Biomass and Species Conservation Value
Doick et al., 2009	Proposed list of sustainability objectives for brownfield greening projects, which include economic benefits, attractiveness, social benefits, health, wellbeing, accessibility, conserve natural and cultural heritage, safety (crime and antisocial behaviour), minimise the use of unrecycled resources, ecosystem services (such as land, water, soil and air quality), protect biodiversity and the natural environment and combat the impacts of climate change

Table 2.11 Worked example for a description of greenspace areas for the study area. Note use (SOPARC tool McKenzie and Cohen (2006) and user quality Gidlow et al. (2018) and biodiversity were averaged across at least 2 years. Note NEST was collected for streets for street greenspaces.

							Use		User quality		Biodiversity (species and habitats)																	
Number	Urban outdoor space ID	Postcode	Ownership	Typology	Street types	Area (hectares)	Use total people observed (week and weekend)	Years SOPARC (2018, 2019)	NEST score	Number of years for nest (2017, 2018, 2019, 2020)	Number of years with bio data (2017, 2018, 2019, 2020)	Species Richness total (average across at least 2 years)	Trees Species Richness	Plants Species Richness	Bird Species Richness	Bee Species Richness	Butterflies Species Richness	Tree cover %	Water cover %	No habitats	Lone trees (y/n)	Stand of trees (y/n)	Grass (y/n)	Rough grass (y/n)	Hedges (y/n)	Water (y/n)	Number of trees	Nearest greenspace
1.	Attock Park	BD3	Public	Urban park		0.76	176	2	76.3	4	3	18	4	7	5	2	0	98.0	0	2	1	0	1	0	0	0		
2.	Back Derby Pass (Laisterdyke)	BD3	Public	Urban park		0.37	68	2	68.3	2	1	15	3	8	1	3	0	30.7	0	2	1	0	1	0	0	0		
3.	Back Margate Road	BD4	Public	Functional / amenity	Grass only	0.11	0	1	59.1	2	2	5.5	0	2	3	0	1	0	0	1	0	0	1	0	0	0		

4.	Baird Street	BD5	Public	Functional / amenity	trees only	0.08	13	1	54.8	2	1	2	1	0	1	0	0	98.0	0	1	1	0	0	0	0	0		
5.	Beech Grove Greenway	BD3	Public	Functional / amenity		2.71	88	2	60.2	3	2	29	7	11	7	3	2	38.52	0	4	1	1	1	1	0	0		
6.	Beech Grove Park	BD3	Public	Urban park		1.88	55	2	70.7	3	2	19	4	7	6	2	1	22.8	0	4	1	1	1	1	0	0		
7.	Bowling Park		Public	Urban park		32.6	1006	2	116.7	4	4	89	44	21	14	5	5	49.6	0	5	1	1	1	1	1	0		
8.	Bradford Moor	BD3	Public	Urban park		6.27	344	2	98.3	4	4	56	22	11	14	3	6	45.0	54	6	1	1	1	1	1	1		
9.	Brassey terrace		Public	Functional /amenity	Grass and	0.13		0	60.1	2	2	11	5	4	3	0	0	17.6	0	2	1	0	1	0	0	0		
10.	Butler street	BD3	Public	Functional /amenity	Grass and	0.81		0	54.0	2	2	24	11	6	6	2	0	15.7	0	2	1	0	1	0	0	0		
11.	Burnett Avenue		Public	Urban park		0.04	5	1	55.5	2	2	18.5	9	4	6	0	1	63.6	0	2	0	1	1	0	0	0		

12.	Canterbury Arc		Local organisation	Urban park		0.49	23	2	64.7	3	2	10	2	7	1	1	0	0.81	0	2	1	0	1	0	0	0		
13.	Canterbury Avenue		Public	Functional /amenity	Grass and	0.29		0	57.9	2	2	8	1	6	1	0	0	2.11	0	2	1	0	1	0	0	0		
14.	Carrington street greenspace	BD3 1	Public	Functional /amenity	Grass and	0.01		0	70.3	2	2	7	2	4	2	0	0	27.3	0	2	1	0	1	0	0	0		
15.	Curzon	BD3	Public	Functional /amenity	Grass and	0.06		0	59.4	2	2	8	1	7	0	0	0	0	0	2	1	0	1	0	0	0		
16.	Curzon/Fitzroy Backstreet	BD3	Public	Functional /amenity	back to back	0.10		0	62.0	1	2	31	27	0	2	2	0	0	0	1	0	0	0	1	0	0		
17.	Emsley Recreation		Public	Formal Recreation		4.12	301	2	95.4	3	3	45	19	9	11	2	4	9.68	0	5	1	1	1	1	1	0		
18.	Fagley Crescent	BD3	Public	Functional /amenity	Grass only	0.16		0	68	2	2	6.5	0	5	2	1	0	0	0	1	0	0	1	0	0	0		
19.	Fitzroy road	BD3	Public	Functional /amenity	Grass and	0.07		0	60.9	2	2	10.5	2	8	0	1	1	0	0	2	1	0	1	0	0	0		

20.	Folkestone Street	BD3	Public	Functional /amenity	Grass and	0.24	64	2	70.2	2	1	11	3	7	1	0	0	56.3	0	2	1	0	1	0	0	0		
21.	Gain Lane	BD3	Public	Formal Recreatio n		1.32	5	2	63.9	3	2	15. 5	5	7	2	1	1	2.42	0	2	1	0	1	0	0	0		
22.	Horton Park	BD5	Public	Urban park		16.3	765	2	106. 5	4	4	63	30	11	13	3	6	55.04	1	6	1	1	1	1	1	1		
23.	Jane Binns	BD5	Public	Urban park		0.05		0	68.4	2	2	7.5	1	3	3	1	0	8.51	0	3	1	0	1	0	1	0		
24.	Kettlewell Drive	BD5	Public	Functional /amenity	Grass only	0.01	6	1	61.2	2	2	12	6	1	5	0	0	2	0	3	0	0	1	1	0	0		
25.	Kyffin Place (Sutton Community Centre)	BD4	Public	Urban park		1.08	94	2	88.9	2	1	30	12	9	6	3	0	30.27	0	4	1	1	1	0	1	0		
26.	Knowles Park	BD4	Public	Urban park		5.06		0	93.0	1	1	31	8	9	2	1	1 1	21.32	0	4	1	1	1	0	1	0		
27.	Laisterdyke Library	BD3	Public	Functional /amenity		0.03	4	1	53.0	2	2	29	12	6	9	1	1	0	0	2	1	0	1	0	0	0		

28.	Latimer Street	BD3	Public	Functional /amenity	Grass and	0.53		0	53.8	2	2	26.5	10	13	2	2	1	86.23	0	4	1	1	1	1	0	0		
29.	Lidl Manchester road	BD5	Public	Functional /amenity	Grass and	0.18		0	48.7	2	2	23	7	9	1	2	5	11.86	0	3	1	0	1	1	0	0		
30.	Manse Street	BD3	Public	Functional /amenity	Grass and	0.11		0	54.6	2	2	11.5	4	7	0	1	0	56.14	0	3	1	1	1	0	0	0		
31.	Marshfield Place	BD5	Public	Functional /amenity	trees only	0.01	9	1	69.5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
32.	Mayfield Centre Park	BD5	Public	Urban park		0.01	18	1	78.0	2	2	13	6	4	3	1	0	27	0	2	1	0	1	0	0	0		
33.	Mir Park	BD5	Public	Urban park		0.01	45	2	72.0	4	3	18	3	6	6	2	1	40.83	0	2	0	1	1	0	0	0		
34.	Morton Road	BD4	Public	Functional /amenity	Grass and	0.21		0	60.0	2	2	22	11	4	6	2	1	33.33	0	2	1	0	0	0	1	0		
35.	Moorlands Ave	BD3	Public	Functional /amenity	Grass and	0.18		0	59.8	1	1	8	2	4	2	0	0	18.18	0	2	1	0	1	0	0	0		

36.	Myra Shay	BD3	Public	Formal Recreatio n		0.09	280	2	95.9	4	4	62	24	18	13	3	4	18.28	0	4	1	1	1	1	0	0		
37.	Newby Primary	BD5	Local school	Urban park		0.01	39	1	84.8	1	0							25	0	2	1	0	1	0	0	0		
38.	Nurser Lane	BD5	Public	Urban park		0.01	41	1	70.3	1	1	9	3	5	1	0	0	28	0	2	1	0	1	0	0	0		
39.	Old Leeds road	BD3	Public	Functional /amenity	Grass and	0.08		0	60.3	2	2	13. 5	6	3	5	1	0	7.894	0	2	1	0	1	0	0	0		
40.	Parkinson Street	BD5	Public	Functional /amenity	Grass and	0.09		0	56.6	1	0							0	0	2	0	0	1	1	0	0		
41.	Parkside Park	BD5	Public	Urban park		1.47	113	2	93.	3	3	24	5	7	6	3	3	13.67	0	2	1	0	1	0	0	0		
42.	Peel Park	BD3	Public	Urban park		26.8		0	114. 9	3	3	56. 5	21	15	13	5	4	56.5	1. 2	6	1	1	1	1	1	1		
43.	Percival street	BD3	Public	Functional /amenity	no green	0.17		0	42.0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

44.	Quaker Lane	BD5	Public	Functional /amenity	Grass only	0.01	6	1	59.2	2	2	17	8	2	5	1	2	0	0	2	0	0	1	1	0	0		
45.	Ransdale Road greenspace	BD5	Public	Functional /amenity	Grass and	0.05		0	69.6	2	2	14	5	7	1	2	0	40	0	2	1	0	1	0	0	0		
46.	Seymour Park	BD3	Public	Urban park		2.17	86	2	88.4	3	2	63	22	22	9	6	4	53.45	0	4	1	1	1	1	0	0		
47.	Sheridan Street	BD4	Public	Functional /amenity	Grass and	0.01	6	1	64.6	2	2	16	8	4	5	0	0	37	0	3	1	0	1	0	1	0		
48.	St Clare's Avenue	BD3	Public	Functional /amenity	Grass and	0.12		0	68.0	1	1	40	4	28	2	2	4	2	0	3	1	0	1	1	0	0		
49.	Shine (St Stevens church)	BD5	Local church	Urban park		0.08	36	1	90.3	2	2	26	12	8	5	2	0	21	0	3	1	0	1	1	0	0		
50.	Spring Mill Street (Castle Street park)	BD5	Public	Urban park		0.01	86	0	78.0	3	3	18.5	9	7	2	1	0	22.68	0	2	1	0	1	0	0	0		
51.	Star Street	BD5	Public	Functional /amenity	Grass and	0.17		0	64.6	2	2	13	4	7	1	1	1	36.79	0	3	1	0	1	1	0	0		

52.	Steadman Terrace greenspace	BD3	Public	Functional /amenity	Grass and	0.17		0	50.1	2	2	8.5	1	6	2	0	0	9.36	0	3	1	0	1	1	0	0		
53.	Sticker Lane	BD4	Public	Functional /amenity	Grass only	0.10		0	50.6	2	2	21	8	5	8	1	1	0	0	2	0	0	1	1	0	0		
54.	The Vine	BD4	Local organis ation	Functional /amenity		0.01		0	55.0	2	2	7.5	3	2	3	0	0	0	0	0	0	0	0	0	0	0		
55.	Thornbury Triangle	BD3	Public	Functional /amenity		0.02	36	2	63.8	2	1	37	18	6	8	3	2	21.28	0	3	1	1	1	0	0	0		
56.	Thornhill Place	BD3	Public	Functional /amenity	Grass and	0.08		0	67.4	2	2	11. 5	6	5	1	0	1	95.26	0	2	0	1	1	0	0	0		
57.	Trident Park	BD5	Public	Urban park		0.72	188	2	77.3	3	2	28	12	8	4	3	1	18.4	0	2	1	0	1	0	0	0		
58.	Tyersal community centre park	BD4	Public	Urban park		2.56		0	98.0	1	1	26	8	6	10	0	1	0.86	0	4	1	1	1	0	1	0		
59.	Upper castle street	BD5	Public	Functional /amenity	Grass and	0.22		0	54.6	2	2	19. 5	7	9	2	0	2	52.07	0	4	1	1	1	1	0	0		

60.	Winchester Gardens	BD4	Public	Urban park		0.14	7	2	79.1	3	2	18	4	8	3	1	2	22.1	0	3	1	0	1	0	1	0		
61.	Woodroyd Centre	BD5	Local nursery	Urban park		0.14	7	2	65.2	4	4	33	11	11	3	5	3	67.9	0	3	1	1	0	1	0	0		
62.	Paley road and Brassey Road	BD4	Public	Street	no green	32.6						1	0		1	0	0	0.0		0	0	0	0	0	0		0	486
63.	Sheridan St and Stafford Road	BD4	Public	Street	trees and	0.08						2	2		2	0	0	9.0		2	1	0	1	0	0		1	154
64.	Fenby Ave and Fenby Grove	BD4	Public	Street	trees and	2.94						5	1		4	1	0	5.0		2	1	0	1	0	0		2	15
65.	Fenby Ave and Bertie St.	BD4	Public	Street	grass only	1.89						2	2		1	1	0	15.0		2	1	0	1	0	0		2	15
66.	Springwood Ave and New Cross St.	BD5	Public	Street	no green	1.41						2	0		2	0	0	0.0		0	0	0	0	0	0		0	7
67.	Birch Ave and Henley Rd	BD5	Public	Street	no green	0.38						1	0		1	0	0	0		0	0	0	0	0	0		0	127

68.	Trickborne Rd. West and Dickens St.	BD5	Public	Street	trees and	0.02						2	3		0	1	1	20		2	1	0	1	0	0		1	23
69.	Ryan St, and Boynton st	BD5	Public	Street	back to back	0.45						0	0		0	0	0	0		0	0	0	0	0	0		0	71
70.	Dawnay Rd. and Tamar St	BD5	Public	Street	no green	16.3						1	0		1	0	0	0		0	0	0	0	0	0		0	250
71.	Little Horton Ave and Central Ave	BD5	Public	Street	trees only	0.72						1	1		1	0	0	1		1	1	0	0	0	0		2	246
72.	Lindley Rd. and Ransdale Rd.	BD5	Public	Street	trees only	0.72						3	1		3	0	0	2		1	1	0	0	0	0		2	21
73.	Marsh St. and Marshfield Pl.	BD5	Public	Street	trees only	0.45						4	3		4	0	0	2		1	1	0	0	0	0		5	223
74.	Cambridge St. and Derby St.	BD5	Public	Street	back to back	2.32						0	1		0	0	0	2		1	1	0	0	0	0		2	25
75.	Stafford Rd and Waverly Terrace	BD5	Public	Street	trees only	0.15						0	3		0	0	0	43		2	1	0	1	0	0		4	4

76.	Staveley Rd. Rugby Rd.	BD5	Public	Street	trees and	2.32						1	2		1	0	0	15		1	1	0	0	0	0		2	132
77.	Legrams Ln. and Princeville St.	BD5	Public	Street	no green	0.37						0	0		0	0	0	0		0	0	0	0	0	0		0	145
78.	Queens ave and Queens Rd	BD3	Public	Street	trees and	32.6						1	4		0	1	0	26		2	1	0	1	0	0		9	250
79.	Kingsdale Cres. and Grove House Dr	BD3	Public	Street	trees and	1.92						1	1		0	1	0	16		2	1	0	1	0	0		4	389
80.	Ashbourne way and Ashbourne Cl	BD3	Public	Street	grass only	5.47						8	0		3	5	0	0		1	0	0	1	0	0		0	140
81.	Acre Lane and Stone Hall Rd		Public	Street	grass only	5.47						3	0		3	0	0	0		1	0	0	1	0	0		0	107
82.	Harrogate Terrace and Harrogate st.		Public	Street	no green	26.8						0	0		0	0	0	0		0	0	0	0	0	0		0	250
83.	In between Falmouth Ave and North Hampton St.		Public	Street	back to back	8.2						1	0		1	0	0	0		0	0	0	0	0	0		0	88

84.	Brookfield Rd. (up near Haslam Close)		Public	Street	trees and	4.42						11	3		11	0	0	45		2	1	0	1	0	0		9	96
85.	Nutall Rd. and Barkerend Rd		Public	Street	no green	0.6						0	0		0	0	0	0		0	0	0	0	0	0		0	42
86.	New Cross St.(west side) near Murgatroyd st.		Public	Street	trees and	1.25						2	4		2	0	0	25		2	1	0	1	0	0		13	220
87.	Legrams Ln. and Princeville St.		Public	Street	no green	0.37						0	0		0	0	0	0		0	0	0	0	0	0		0	145
88.	Queens ave and Queens Rd		Public	Street	trees and	32.6						1	4		0	1	0	26		2	1	0	1	0	0		9	250
89.	Kingsdale Cres. and Grove House Dr		Public	Street	trees and	1.92						1	1		0	1	0	16		2	1	0	1	0	0		4	389
90.	Ashbourne way and Ashbourne Cl		Public	Street	grass only	5.47						8	0		3	5	0	0		1	0	0	1	0	0		0	140
91.	Acre Lane and Stone Hall Rd		Public	Street	grass only	5.47						3	0		3	0	0	0		1	0	0	1	0	0		0	107

92.	Harrogate Terrace and Harrogate st.		Public	Street	no green	26.8						0	0		0	0	0	0		0	0	0	0	0	0		0	250
93.	In between Round St. and St. Stephen's rd.		Public	Street	back to back	1.25						0	0		0	0	0	0		0	0	0	0	0	0		0	212
94.	Baird St. and Spring Mill St.		Public	Street	trees only	0.9						3	2		3	0	0	8		1	1	0	0	0	0		4	170
95.	St. Luke's Cl. and Park Lane		Public	Street	no green	0.9						0	0		0	0	0	0		0	0	0	0	0	0		0	179
96.	Bolingbroke st. and Unnamed Rd.(runs parallel to A6177)		Public	Street	trees only	0.14						1	2		1	0	0	9		1	1	0	0	0	0		5	74
97.	In between Rathmell St. and Carr bottom Rd.		Public	Street	back to back	0.58						0	0		0	0	0	0		0	0	0	0	0	0		0	95
98.	White Lane and Wisbey Bank		Public	Street	trees and	4.65						3	1		0	3	0	1		2	1	0	1	0	0		1	61
99.	Elmfield Dr and Thornfield Ave		Public	Street	grass only	0.1						0	0		0	0	0	0		1	0	0	1	0	0		0	139

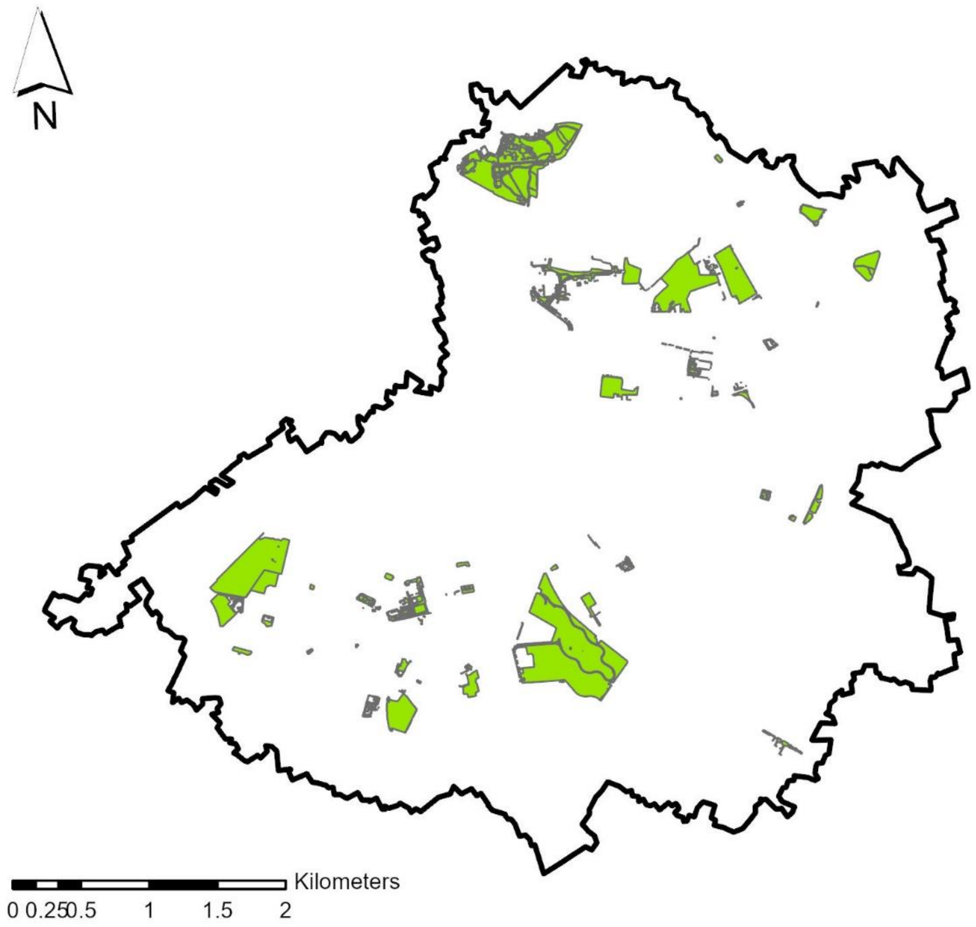


Figure 2.2. A map of the urban greenspaces in the study area (Little Horton, Bradford Moor and Bowling wards of Bradford) showing greenspace distribution and size. Contains OS data © Crown Copyright OS Open Green Space (2023).

3 Measuring 'Green' Exposure and Health Outcomes in a Deprived Urban Community in the UK: A comparison of traditional methods to alternative methods including biodiversity and street-level methods

3.1 Abstract

There is growing evidence of positive associations between greenspace and health outcomes. However, previous studies have used simple spatial approximations of green space exposure based on the proportional cover of natural space within a certain distance of a location, and satellite-derived measures of "green" (such as Normalized Difference Vegetation Index, NDVI) that lack detail about the structure of the natural environment. Such approaches neglect potentially important elements of greenspace quality such as biodiversity or usability that can influence how people use greenspaces and gain any associated benefits. Here, I explored two different measures of exposure (buffer and network) for eight measures of "green", across three distances (50m, 100m and 300m) for 12 health outcomes (including birthweight, wellbeing and allergies) drawn from large longitudinal health datasets from Born in Bradford (N= 2644 and 5240 pregnant women and children under the age of 4 years old). I tested for a difference between the proportion cover of green space around a participant's home (buffer) and the exposure along linear walking routes (network method). I found no relationship between green space exposure calculated using buffer and network methods, demonstrating that these two approaches are measuring green exposure in different ways. Varying associations between greenspace measures and health outcomes were found. In general, more nuanced measures of green exposure (such as exposure to varying species richness) had greater explanatory power compared to simpler NDVI measures. The findings of this exploratory study suggest that the integration of greenspace quality and network methods of measuring exposure may enhance future studies of greenspace health benefits, particularly for street-level interventions. However, NDVI has a similar level of explanatory power to the alternative measures and methods included in this study, so in theory, it could be used as a proxy for these measures. Psychosocial factors such as satisfaction and use of greenspace were also recorded for a subsample, with satisfaction with the local area having the greatest explanatory power for BMI, depression, anxiety and wellbeing.

3.2 Introduction

Although urban environments can offer opportunities for health and wellbeing, these landscapes are also associated with a range of health problems. For example, city populations are exposed to health threats such as air pollution, increased temperature through the heat island effect, noise, and the spread of disease (Alirol et al., 2011; Rydin et al., 2012; Nieuwenhuijsen, 2016). These threats can result in negative health outcomes including reduced lung function, lower birth weight, and increased blood pressure (Paunović et al., 2011; Pedersen et al., 2013; Nieuwenhuijsen, 2016). Simultaneously, non-communicable diseases such as cardiovascular disease, cancer, diabetes and stroke, as well as mental health disorders, are all increasing (Beaglehole et al., 2011; Collins et al., 2011; Corbett et al., 2018).

There is growing evidence that greenspace and the natural environment can positively influence health outcomes (Lovell et al., 2014; Lee et al., 2015; World Health Organization, 2016; Cox et al., 2018; Cronin-de-Chavez et al., 2019; Marselle et al., 2021). Blue spaces also influence health outcomes but are outside the scope of this study (Wheeler et al., 2015; White et al., 2020). There is a range of mechanisms for how green infrastructure and biodiversity might provide benefits for health and wellbeing, through active pathways such as promoting positive mental health, providing context and motivation for physical activity or social gatherings and recreation (Lovell et al., 2014; Lee et al., 2015; Cox et al., 2018; Cronin-de-Chavez et al., 2019; White et al., 2020; Marselle et al., 2021). Passive pathways can contribute to health through exposure by stimulating healthy microbiomes and mitigating health risks such as the heat island effect, noise pollution, flooding and, poor air quality (Hanski et al., 2012; Dadvand et al., 2012; Lovell et al., 2014; Lee et al., 2015; Marselle et al., 2021). Greenspaces can encourage health-promoting behaviours such as physical activity and facilitate higher wellbeing for those exercising in greenspaces compared to other contexts (Coombes et al., 2010; Lachowycz et al., 2012; Lovell et al., 2014; Marselle et al., 2021; Legrand et al., 2022; Kelley et al., 2022). It is important to note that urban greenspaces can also be a source of disservices to people and these can affect health and wellbeing outcomes. Disservices can range from aesthetic (such as untidy vegetation or pest animals), economic (costs of removing harmful species), environmental (reduction in species diversity or introduction of non-native or invasive species) and health and safety (allergies, unsafe water features, wild animals) (Lyytimäki et al., 2008; Escobedo et al., 2011; von Döhren and Haase, 2015; Potgieter et al., 2017; Brindley et al., 2019; Birch et al., 2020; Marselle et al., 2021).

To address some of the urban-lifestyle health risks and inequalities it is important to understand the relationship between exposure to green (natural environments) and health and wellbeing. There is evidence for relationships between greenspace exposure (such as greenness, greenspace area or distribution, proximity, and greenspace use) and health outcomes. For example, *surrounding greenness* can have positive associations with weight, birth weight, depressive symptoms, blood pressure, diabetes and wellbeing (Dadvand, Wright, et al., 2014; Dadvand, Wright, et al., 2014; McEachan et al., 2016; Klompmaker et al., 2018; McEachan et al., 2018; Yang et al., 2019; Warembourg et al., 2021; Luque-García et al., 2022). While the *lack of green* is also associated with poor health outcomes such as increasing depression symptoms, lower wellbeing, higher blood pressure in women and children, and risk of cholesterol and diabetes (White et al., 2013; Alcock et al., 2014; Wheeler et al., 2015; Rautio et al., 2018; Plans et al., 2019; Warembourg et al., 2021). The *area* of greenspace has also been shown to have an association with positive health outcomes such as higher wellbeing (White et al., 2013). The *spatial distribution* of greenspaces has also been linked with health outcomes, for example, large greenspace patches that are well interspersed with the built environment are also associated with lower levels of poor health (Mears, Brindley, Jorgensen, et al., 2019). Associations between the *quality* of the greenspace and health and wellbeing have also been found (Cronin-de-Chavez et al., 2019; Knobel et al., 2019; Mears, Brindley, Baxter, et al., 2020; Knight et al., 2022). Poor quality greenspace may reduce use or act as a disservice (Lee et al., 2015; Cronin-de-Chavez et al., 2019; Birch et al., 2020). For example, higher quality surrounding urban greenspace was associated with a higher likelihood of moderate-to-vigorous physical activity and a lower risk of overweight/obesity, as well as increased greenspace use (Knobel et al., 2021).

There is growing evidence that the biodiversity in greenspaces promotes health or wellbeing benefits through changing patterns of use, positive attitudes and perceptions of spaces (Fuller et al., 2007; Dallimer et al., 2012; Lovell et al., 2014; Hoyle et al., 2017; Cox et al., 2018; Public Health England, 2020; Cameron et al., 2020; Dobson et al., 2021; Marselle et al., 2021). In particular, birds, trees and flowers have been linked to higher wellbeing (Dallimer et al., 2012; Wheeler et al., 2015; Hoyle et al., 2017; Wood et al., 2018; Wyles et al., 2019; Cameron et al., 2020; Methorst et al., 2021). As with greenspace, a lack of biodiversity can be related to poor health outcomes. For example, Knight et al. (2022) found that living further than a 1 km walk from a high-quality public natural site with high biodiversity was related to lower levels of life satisfaction. Biodiversity of greenspaces can be overlooked by traditional methods of measuring green exposure via NDVI. However, a review found that few greenspace studies explored health and biodiversity simultaneously, the authors claim that ‘in the past, there has been negligible cross-disciplinary research that knits biological science and public health together' and state that interdisciplinary work is required to understand the mechanisms that explain the health and wellbeing effects of exposure to biodiversity (Lai et al., 2019).

Greenspace use (frequency and duration) can have a positive associations with mental health and wellbeing, self-reported health, social cohesion, physical activity and lower prevalence of high blood pressure (Shanahan et al., 2016; Cox et al., 2018). Benefits are experienced through as little as 30 minutes once a week but to maximise benefits, it is recommended that people should use greenspace for more than 120min a week (Shanahan et al., 2016; White et al., 2019). However, similar gains can be had by combining shorter, everyday visits to greenspace, with potential for wellbeing benefits to be sustained for at least a month (Natural England, 2010; Rupprecht and Byrne, 2014; Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Lovell et al., 2020; Dobson et al., 2021). Benefits of visiting greenspaces (such as physical health, social cohesion and improved physical activity) can be independent of the surrounding residential environment; people with less access to greenspace can have similar gains in health if they choose to frequently visit greenspaces (Cox et al., 2018). Therefore, it is important to capture greenspace use and the mediators of greenspace use.

Psychosocial factors such as perceptions of local greenness (the amount, quality and biodiversity) can influence the use of greenspace and any associated health and wellbeing outcomes (Dallimer et al., 2012; Hoyle et al., 2017; McEachan et al., 2018; Abbasi et al., 2020). McEachan et al. (2018) found that satisfaction with local greenspace was more important than quantity of greenspace for the wellbeing of 4-year-olds. Even if greenspace is physically available and accessible, community context such as low social cohesion or anti-social behaviour can reduce walkability and limit visits, perpetuating health inequalities through differentiated greenspace access within local populations (Seaman et al., 2010). Social factors such as population density have been found to be more important than physical aspects of greenspaces in influencing visits (Lo and Jim, 2010). Cronin-de-Chavez et al. (2019) found that fear of crime, antisocial behaviour and accidents were the overriding barriers to use, even in high-quality spaces. Alternatively, urban communities with higher residential greenness have been found to have a stronger sense of community (Cox et al., 2018). Previous studies have also found unequal distribution of greenspace benefits across income and ethnicity (Dadvand, Wright, et al., 2014; McEachan et al., 2016; Rigolon, 2016; Wood et al., 2018; McEachan et al., 2018; Ferguson et al., 2018; Corley et al., 2018; Cronin-de-Chavez et al., 2019; Mears, Brindley, Maheswaran, et al., 2019; Islam et al., 2020; Burnett et al., 2021). Previous research in the study area also found that even if access is similar that there can be differences in the associated benefits of greenspace. For example, proximity to greenspace was positively associated with higher birth weights for children of White British origin, but not children of other ethnicities (Dadvand et al., 2014). Yet, there were stronger associations between reduced likelihood of depressive symptoms in pregnant women and higher residential greenness for those from more disadvantaged backgrounds (McEachan et al., 2016). McEachan et al. (2018) also found that satisfaction with green space was significantly associated with fewer behavioural difficulties for South Asian children and not white British Children.

Measuring green access and exposure in urban environments

Greenness and greenspace can refer to a variety of elements in the built and natural environment and there is no consensus on a definition for greenspace as there are a variety of existing interpretations (Lovell et al., 2014; Taylor and Hochuli, 2017). However, the 'green' usually refers to vegetation and these spaces can range from formal gardens to roadside amenity grass verges. Although greenspace can be described as private or public, many studies refer to recreational or undeveloped land that is usually managed for the public and often accessible from residential properties (Taylor and Hochuli, 2017). In this study, I refer to spaces that are urban and publicly accessible (such as parks, playing fields, woods and amenity grass associated with road and rail networks), with varying levels of vegetation and biodiversity.

Traditionally, studies have measured access to greenspaces using set distances from a home address to the nearest park or nature reserve of a certain size (0.5 hectares, 1 ha, or 2 ha) (Rojas-Rueda et al., 2019; Jarvis et al., 2020). Green exposure is then usually quantified as the proportional value of natural space (often excluding smaller informal spaces) within a specified area (such as a buffer area around a residence)(Rojas-Rueda et al., 2019; Jarvis et al., 2020). Buffer sizes can vary from 50m for immediate exposure (relating to health outcomes such as wellbeing) to larger sizes of 1500m (a 20-minute walk relevant for physical activity) but very often 200m, 300m and 500m are used (Markevych et al., 2017; Rojas-Rueda et al., 2019; Jarvis et al., 2020). Currently, there is no consensus on which buffer size might have the strongest link with health outcomes (Matthews and Yang, 2013; Browning and Lee, 2017; Jarvis et al., 2020). Associations between physical activity opportunities and buffer sizes are inconsistent, with studies finding different relationships at different sizes (Roux et al., 2007; Christensen et al., 2022). For example, a study in the Netherlands, the proportion of greenspace was positively associated with physical activity within a 400 m buffer, but not 800 m or 1600 m buffers (Jansen et al., 2018). Researcher-defined buffers are different to perceived or actual areas of use by individuals, their definition of the neighbourhood is different from that of predefined buffers and do not accurately measure day-to-day choices (Laatikainen et al., 2018; Rojas-Rueda et al., 2021; Christensen et al., 2021; Christensen et al., 2022). Christensen et al. (2021) claim that buffers only capture two-thirds of an individual's daily movement. However, (Christensen et al., 2021) also found that self-drawn neighbourhoods capture even less (10%) of individual daily movement.

Therefore, buffer methods can neglect the everyday lived exposure to informal greenspace (such as street-level), which is important for health and wellbeing (Natural England, 2010; Rupprecht and Byrne, 2014; Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Lovell et al., 2020; Dobson et al., 2021). Informal greenspace offers benefits for communities by providing green areas in urban environments that may otherwise be used, aesthetic value, offer play spaces for children, dog walking, gardening, short cuts, meeting places, relaxation and conservation areas (Rupprecht and Byrne, 2014). The mechanisms for health benefits may differ between active access and use of greenspace (e.g. physical activity) or passive exposure to green elements (e.g. improved air quality, cooling) experienced by individuals moving through the built environment on a day-to-day basis (Haines-Young and Potschin, 2018; Díaz et al., 2018; Jarvis et al., 2020).

Both exposure and access can be measured at the neighbourhood or city level. Jarvis et al. (2020) claim that most studies suggest stronger health relationships with exposure than with accessibility; they recognise that results are largely inconsistent. The measures of exposure are often satellite-derived measures such as the Normalized Difference Vegetation Index (NDVI) or land cover, therefore the scale of these measures (30-100m) may miss important street-level differences in green exposure. Helbich et al. (2019) found that street view green and blue spaces were uncorrelated with satellite-derived metrics (NDVI and land cover). These measures, particularly access, can neglect the quality of the greenspace. Or assume greenspace quality based on greenspace size but there are additional aspects of quality that should be explored (such as access, safety, social context and inclusion, aesthetics and biodiversity)(Corley et al., 2018). McEachan et al. (2018), a study of the same population (data) and area was a unique study as it compared the association between wellbeing and a NDVI-based measure of surrounding greenspace to a measure of greenspace quality (satisfaction). McEachan et al. (2018), found that, when controlling for covariates of socio-economic status, the alternative measure of greenspace quality (satisfaction) was a better predictor for wellbeing than the NDVI-based measure.

High exposure or access to greenspace may not correlate with safe or useable areas (Jarvis et al., 2020). Access or exposure to a poor-quality greenspace may act as a disservice to health or wellbeing outcomes. For example, high-density green space (such as woodland) of poor quality may be seen as an area of anti-social behaviour and dangerous to use (Schroeder and Anderson, 1984; Jorgensen et al., 2002; Bell et al., 2003; Jansson et al., 2013; Birch et al., 2020). Greenspaces in deprived areas or more racially diverse areas may have lower access, safety and aesthetic value (Corley et al., 2018). Therefore, greenspace quality should be measured and monitored as decision-makers and stakeholders can use this to inform management for wellbeing of the surrounding communities (Knobel et al., 2019).

To summarise, traditional methods measuring access or exposure to greenspaces often rely on using buffers of set distances, to measure access to greenspaces of a certain size or satellite-derived ‘greenness’. This leads to:

1. Assuming all greenspace in the buffer offers equal access or exposure, neglecting the lived experience of moving through the built environment where features maybe inaccessible or of low quality. This approach can overlook the street-level exposure to green, particularly if only greenspaces of a certain size are included.
2. An assumption that all greenspace is of equal quality (for people or nature), neglecting that low-quality greenspaces could act as a disservice and negatively impact health outcomes.
3. Neglecting psychosocial factors such as perceptions of greenspaces can influence health and wellbeing outcomes and the use of greenspaces. Studies may not consider the frequency or duration of use of greenspaces.

To unpick these assumptions, in this in this study I explore multiple measures of green exposure (greenspace area (all sizes vs only large >2ha), species richness of surrounding greenspace, user quality greenspace, NDVI, land cover (grass, broadleaved woodland, urban)). I use two methods to measure exposure: traditional buffer and walked network across three distances (immediate exposure 50m and 100m and 5 min walk 300m). I also included psychosocial factors such as satisfaction with local greenspace and the use of greenspace (frequency and duration). I explored multiple health outcomes (Body Mass Index (BMI), depression, anxiety, wellbeing, birth weight, blood pressure, gestational diabetes, asthma, hay fever, rhinitis, eczema and insect bites). I build on previous research that explores links between green exposure and health for pregnant women and children (such as Dadvand, Wright, et al., 2014; McEachan et al., 2016; McEachan et al., 2018; Warembourg et al., 2019; Warembourg et al., 2021) and use data from the Born in Bradford longitudinal health studies that are well-established, long-running datasets on health outcomes for the population. I coupled this health data with the detailed data on biodiversity and the nature environment for the study area (building on the work of Wood et al. (2018). Note the focus of this chapter is the exploratory data analysis to compare different measures of greenspace rather than to identify associations with specific health outcomes.

There is potential for confounding variables to be present in these types of studies that explore associations between greenspace and health variables, such as more affluent areas have higher quality greenspace and better healthcare or provision which can influence their health outcomes. Therefore, care should be taken to interpret the results do avoid assuming causality between greenspace variables and health. In this study socio-economic factors such as deprivation, income, education, support networks, pre-existing poor health or family history of poor health were measured and taken into account (see '*sample population'* section in 3.4 Results).

The following hypotheses are explored:

H1: Network measures of exposure better predict relationships between greenspace and health outcomes than buffer-based measures.

H2: Alternative measures of greenspace (such as species richness or quality) better predict relationships between greenspace and health outcomes than simpler measures based on NDVI.

H3: Greenspace satisfaction or use will better predict relationships between greenspace and health outcomes than spatial measures of green exposure.

3.3 Methods

Study Setting

This study was set in Bradford, a large urban city located in the north of England, United Kingdom, with a population of over 500,000 people (2021 census, Bradford Metropolitan District Council, 2022a). Bradford is a historic city that grew out of the industrial revolution; its landscape has been influenced by manufacturing with high inner-city housing density surrounding historic sites such as mills (similar to Sheffield, (Mears, Brindley, Jorgensen, et al., 2019)). Bradford has high levels of ill health, with higher than UK average prevalence of obesity (adult and child), diabetes, common mental health disorders (such as depression), incidence of wheezing disorders amongst children and lower birth weight in babies (Bradford Metropolitan

District Council, 2016; Mebrahtu et al., 2016; Office for Health Improvement and Disparities, OHID, 2021).

The study took place in three electoral areas (wards): Little Horton, Bowling and Barkerend, and Bradford Moor (IMD, 2019). This study is part of the wider work on the Better Start Bradford Better Place Project, which aims to improve health outcomes for children under 4 years old in these three wards (Better Start Bradford, 2023). These wards are within the 10% most deprived wards in England on the Index of Multiple Deprivation (IMD, 2019)(ranked as wards with the 2nd, 3rd and 4th highest deprivation within the 30 districts of Bradford). The average life expectancy was lower than or close to the district average for all wards for both males (Bradford: 77.7 vs study area: 73.5-76.3 years) and females (Bradford: 81.5 vs study area: 78.3-82.2) and lower than the national average (males: 79.3 vs females: 83.1)(The Office for National Statistics, ONS, 2021; Bradford Metropolitan District Council, 2022b).

Sample

Participants are from two birth cohorts hosted with the Born in Bradford research programme – the Born in Bradford's Better Start (BSB) cohort (Dickerson et al., 2016; Dickerson et al., 2022) and the Born in Bradford (BiB) family cohort (Wright et al., 2013). The BSB, data set includes 2644 mothers recruited between 1st April 2016 and 8th March 2020 (Figure 3.1, Table 3.1). The BSB cohort was set up in 2016 to recruit pregnant mothers living within the BSB area (Little Horton, Bowling and Barkerend, and Bradford Moor).

I only included a sub-sample of the BiB cohort that lived in the BSB wards at the time of recruitment (baseline survey: 5240)(Table 3.1). The BiB cohort recruited pregnant mothers booked to give birth at the city's primary maternity unit for the study between 2007-2011. BiB cohort participants give consent for long-term follow-up for themselves and their child (including routine data links)(Wright et al., 2013; Dickerson et al., 2016). Ethical approval was obtained from the NHS Bradford-Leeds Research Ethics Committee (BSB: 15/YH/0455; BiB: 07/H1302/112).

Health outcomes

Mother and baby

I included a range of health outcomes for mothers, this included body mass index (BMI), blood pressure and gestational diabetes, which have been linked to green space metrics. Body Mass Index (BMI) was used as a proxy for body fat (Keys et al., 1972) which is correlated with other measures and health and wellbeing outcomes, such as cardiovascular disease (Freedman et al., 2009), cancer (Bhaskaran et al., 2014), or depression (Luppino et al., 2010). BMI was collected through baseline surveys when the participant was pregnant (BSB and BiB, Table 3.1).

Blood pressure and gestational diabetes data was collected from linked maternal and infant health records around the time of the BiB pregnancy and births were registered (see Table 3.1). To explore the effect of exposure to greenspace on blood pressure I converted the systolic and diastolic readings into Mean Arterial Pressure (MAP). This is the 'average arterial pressure throughout one cardiac cycle, systole, and diastole' essentially measuring if there is sufficient blood flow to vital organs (too high or low can cause health impacts)(DeMers and Wachs, 2022). Gestational diabetes mellitus (GDM) is one of the most common medical complications of pregnancy, it causes high blood sugar and can negatively impact the health of the mother or baby (American College of Obstetricians and Gynecologists, 2018).

I also used birthweight data to explore the health of new-borns in the study area. I split the sample into three groups: unhealthy-low, healthy, and unhealthy-high birthweight. Low birthweight is when the baby weighs less than 2500 g regardless of gestational age (Cutland et al., 2017). High birthweight (macrosomia) is usually when a baby weighs more than 4,000 g regardless of gestational age and increases the likelihood of labour abnormalities, shoulder dystocia, birth trauma, and permanent injury to the baby (American College of Obstetricians and Gynecologists, 2020). In this study, healthy birthweight is defined as 2501-3,999 g.

Mother's mental health and wellbeing

I explored depression, anxiety and welling through self-reported questionnaires completed during the initial recruitment period for BSB (see Table 3.1). Depression was measured using the Patient Health Questionnaire (PHQ) where participant's scores indicate severity (none: 0-4, mild: 5-9, moderate: 10-14, moderately severe: 15-19, severe: 20-27)(Kroenke et al., 2001). Anxiety was measured using the General Anxiety Disorder (GAD) where a participant's score indicates severity (minimal: 0–4, mild anxiety: 5–9, moderate anxiety: 10–14, severe: 15–21)(Spitzer et al., 2006). For measuring wellbeing, I used the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS), specifically the shorter 7-item scale (SWEMWBS) higher score indicates better wellbeing (< 17 probable depression, 18-20 possible depression, 21-27 for average, 28-35 high wellbeing)(Stewart-Brown et al., 2009; Shah et al., 2021).

Allergies in children

I explored a range of allergy outcomes in children aged four (asthma, allergic rhinitis, hay fever, eczema and insect bites). This data was collected through questionnaires to participating parents when the child was 4 years old (see Table 3.1). Asthma is associated with inflamed airways and increased mucus production, which can limit airflow (Global initiative for Asthma, 2021). Allergic rhinitis is an allergic reaction triggered by pollen, dust or pets (such as cats, dogs or feathers)(Ng et al., 2000). The seasonal version, often referred to as hay fever causes increased irritation in the spring and autumn when more airborne pollen. Atopic dermatitis (eczema) is irritation of the skin which can be red and scratchy, there are a few triggers that can include contact with certain plants (such as dandelion)(Esser et al., 2019). I also explored if the child had any allergic reaction to insect bites. Here I used the sub-sample of the Born in Bradford data (n=955 of 5240 sub-sample of total BiB data) this data on allergies was collected through systmOne primary care data which allows clinicians to record data during consultations with patients and is used by all general practitioner surgeries in Bradford (Mebrahtu et al., 2016; Skeenaghan, 2020).

Measures of green exposure

Greenspace availability

I used OS Open Greenspace (Ordnance Survey Limited, 2021a) to record the distribution and area of greenspace in the study area. I generated greenspace maps by type and size that I used for the geospatial analysis to understand access to greenspace of two types: (i) all greenspace and (ii) greenspace equal or larger than 2 ha.

Table 3.1. Health outcome data sets, collection and sample size

Health outcome	Collection	Data set	Sample size	Type of variable
BMI (mothers)	BSB: baseline survey during pregnancy	BSB	953	Continuous
	BiB: baseline survey during pregnancy.	BiB	3484	
Depression (mothers)	BSB: baseline survey during pregnancy	BSB	1935	Continuous
Anxiety (mothers)		BSB	2467	Continuous
Wellbeing (mothers)		BSB	2644	Continuous
Birthweight (children)	BSB: Maternity records	BSB	2508	Binary
Blood pressure (mothers)	BiB Pregnancy data set: maternal and infant health records around the time of the BiB pregnancy and birth	BiB	937	Continuous
Gestation diabetes (mothers)		BiB	4008	Binary
Asthma (children)	BiB subset of MeDALL parent answers questionnaire when the infant is age 4.	BiB	954	Binary
Hay fever (children)		BiB	955	Binary
Allergic rhinitis (children)		BiB	955	Binary
Eczema (children)		BiB	954	Binary
Allergic reactions to insect bites (children)		BiB	954	Binary

Greenness

The Normalized Difference Vegetation Index (NDVI) is a standardized, satellite-derived index approximating greenness (relative biomass). I used data from MODIS Vegetation Index (Terra 250m, MOD13 Series, USGS and NASA) (Didan, 2015) and took an average of the NDVI layers between May and August for 2018 and 2019 when there is maximum vegetation cover for the location (matching methods from Dadvand, Wright, et al., 2014; McEachan et al., 2018).

I also measured exposure to ‘green’ or ‘grey’ land cover (grass or broadleaved woodland vs urban). I used the raster data sets for the UK (Morton et al., 2020). I reclassified the land cover to make three maps showing the coverage of (1) grass (improved grassland and semi-natural grassland), (2) woodland (only broadleaf woodland was present in the study area so coniferous woodland was not included), and (3) urban cover (built-up areas).

Greenspace quality: User quality and biodiversity

A total of 58 greenspaces of varying size (0.001 – 32.6 ha) and type (formal recreation/sports fields: 3, amenity: 32, urban park: 23) located within the three participating wards were visited to collect data on user quality and biodiversity. The Natural Environment Scoring Tool (NEST; Gidlow et al., 2018) was used to assess the presence/absence of features and condition of the environment to evaluate the overall quality of the parks and other green spaces. A higher score indicates a higher quality of amenities. The tool involves summing scores for each greenspace across eight categories: access, recreation facilities, amenities, aesthetics (natural and non-natural), incivilities, safety, and usability. As the scoring is subjective, at least two researchers scored each greenspace across all categories to allow for an average score for each park to be calculated. Data collection took place in 2018 and 2019; there was no significant difference between the years, therefore scores were averaged for each greenspace.

To provide a measure of biodiversity, transects that crossed each type of habitat in the greenspace were used to record birds, bees, butterflies, and trees 2.5 m either side of the transect (Pollard et al., 1986; Fuller et al., 2007). Transects were carried out at times that would represent common user experiences of biodiversity (8.30 am – 5 pm). Transects were also conducted when there were appropriate conditions (May – August 2018, 2019, 2020)(Carvell et al., 2017). Transects were the same route each year and selected by a route that passed through each habitat aiming to keep effort as consistent as possible across sites (approx. 20 min walk for each). Plants (excluding grass) were identified to species-level through randomly placed quadrats (1m x 1m) in each habitat type (such as grass, scrub, and woods) (5 repeats for each habitat type). Species richness (total number of species) was calculated for birds, pollinators (bees and butterflies), trees, and other plants, and as a total for each greenspace. Wildlife guides were used to identify pollinator species (such as the Big 8 Guide by Bumblebee Conservation Trust and the Big Butterfly Count ID chart by Butterfly Conservation). Biodiversity data collection was conducted at least twice two weeks apart in each year (2018, 2019 and 2020), for example, two transects per greenspace each year and the data from the repeats was averaged for each greenspace.

I used the Ordnance Survey OS MasterMap Greenspace data to determine the area and type/function of greenspaces (Ordnance Survey (GB), 2020). I used the area of greenspace to predict the species richness and NEST of the remaining 7,367 greenspaces that were not sampled as part of the field surveys. This was because the log area in hectare explained 63% of the variance in species richness and 67% of NEST values.

Street level measurement

To assess the street-level greenspaces, I walked 61 streets (n= 4,689 total roads/streets in the study area) at a range of distances (250 m, 500 m, 750 m, 1000 m) from larger (>2ha) greenspaces (Bowling Park, Peel Park, Horton and Myra Shay-Bradford Moor Park) in the four compass directions (North, East, South, West) moving away from the greenspace. I treated each 100 m stretch of street as a transect in the same way as the park biodiversity surveys (see above). I used these 61 streets to validate street typologies for the street network in the study area. I excluded any biodiversity in gardens to focus on the contribution of public greenspaces. Field observations and satellite images of the study area also show that within the study area, back gardens often comprised small square plots of concrete that back onto concrete or tarmac alleys. While some houses did have front gardens, their biodiversity varied greatly. I also recorded the NEST score for 28 streets, which were part of the data collection for paired sites associated with the Born in Bradford Better Place Project.

Roads were categorised into broad types based on the level of "green": 1) no green (grey streets), 2) grass only, 3) tree only, 4) tree and grass. I ran a general linear model and only the type of street had a significant relationship with street-level species richness (trees and grass: $p= <0.01$, and grass only $p= <0.01$), whereas the distance from the nearest greenspace and size of greenspace was not significant ($p=0.12$ and $p= 0.80$). I included the size of the nearest greenspace and distance from the nearest greenspace in case there was spill over of biodiversity from larger greenspaces to close by streets which may impact the quality of street-level green exposure. This analysis showed that there was no spill over of the biodiversity from greenspaces to the surrounding streets and I could use the street type to predict the biodiversity of greenspaces on the streets as there was no added biodiversity benefit from living next/close to a large greenspace. As a result, I assume that all streets of the same type would have the same biodiversity value. I categorised the remaining streets (n=4,689, 287.70 km) in the study area into four types using aerial imagery (EDINA Digimap, 2018) and OS Open Roads layers (Ordnance Survey Limited, 2021b). This was used to predict the biodiversity and quality (NEST) on a street-level based on the street type. These predicted values based on real-world measures were then used for network methods of measuring greenspace biodiversity and quality.

Greenspace Exposure GIS

I explored two methods for measuring greenspace exposure: a) buffer (Euclidean distance from individual points) and b) network (distance travelled along road networks by passing through cells up to a defined distance in all possible directions from a point). Since the landscape characteristics that best predict the benefits of greenspace are unclear, I measured exposure to a range of different green space variables: area of greenspace (all sizes), area of greenspace larger than 2ha, species richness of surrounding greenspace, quality of surrounding greenspace, NDVI, and the area covered by grassland, broadleaved woodland, and urban land use and four street types (Table 3.2). The majority of the greenspaces included in this study (98.7%) were amenity grassland, which was usually open with full access rather than having designated entry points so I did not integrate access points for network methods. I measured the exposure to green for three distances (immediate exposure at 50m and 100m, and a 5 min walk at 300m). In the UK, a government agency recommends that there should be a greenspace at least 2 ha in size within 300 m of where they live, as this is a distance perceived to be accessible for those with children or disabilities (Natural England, 2010). A study of walking behaviour in a city found that most walks were shorter than 600m (Millward et al., 2013).

Table 3.2 The green exposure variables used in this study, including buffer and network methods and greenspace satisfaction and use. The number in each variable name represents the distance (50, 100 or 300 m).

	Both Better Start Bradford and Born in Bradford data sets Spatial Measures Buffer	Network
Greenspace area	50 all green area sum 50 all green area average 100 all green area sum 100 all green area average 300 all green area sum 300 all green area average 50 2ha green area sum 50 2ha green area average 100 2ha green area sum 100 2ha green area average 300 2ha green area sum 300 2ha green area average	NA
Species Richness	50 all green Species Richness average 100 all green Species Richness average 300 all green Species Richness average 50 2ha green Species Richness average 100 2ha green Species Richness average 300 2ha green Species Richness average	
User quality (NEST)	50 all green NEST average 100 all green NEST average 300 all green NEST average 50 2ha green NEST average 100 2ha green NEST average 300 2ha green NEST average	
Land cover: urban	50 urban mean 100 urban mean 300 urban mean	
Land cover: broad-leaved woodland	50 wood mean 100 wood mean 300 wood mean	
Land cover: grass	50 grass mean 100 grass mean 300 grass mean	
NDVI	50 NDVI average 100 NDVI average	

	300 NDVI average	
Street-level: species richness	N/A	50 Species Richness streets 100 Species Richness streets 300 Species Richness streets
Street-level: user quality (NEST)	N/A	50 NEST streets 100 NEST streets 300 NEST streets
Street-level Green (road type)	N/A	50 RoadType0 no road 100 RoadType0 no road 300 RoadType0 no road 50 RoadType2 no green 100 RoadType2 no green 300 RoadType2 no green 50 RoadType3 tree only 100 RoadType3 tree only 300 RoadType3 tree only 50 RoadType4 grass only 100 RoadType4 grass only 300 RoadType4 grass only 50 RoadType5 grass and tree 100 RoadType5 grass and tree 300 RoadType5 grass and tree
Non-spatial measures		
Better Start Bradford only		
Greenspace Use	Visits to public greenspace in summer Visits to public greenspace in winter	
Local satisfaction	Area Greenspace	
Born in Bradford only		
Greenspace use: garden	Home has garden	
Greenspace use: garden (summer)	Weekdays: average days in garden in summer Weekend: average days in garden in summer Average days in garden in summer Weekdays: average minutes per day during weekdays in garden in summer Weekend: average minutes per day in garden in summer Average minutes in garden in summer	
Greenspace use: garden (winter)	Weekdays: average days in garden in winter Weekend: average days in garden in winter Average days in garden in winter Weekdays: average minutes per day in garden in winter Weekend: average minutes per day in garden in winter Average minutes in garden in winter	
Greenspace use: public spaces (summer)	Weekdays: average days in park in summer Weekend: average days in park in summer Average days in park in summer Weekdays: average minutes per day during weekdays in park in summer Weekend: average minutes per day in park in summer Average minutes in park in summer	
Greenspace use: public spaces (winter)	Weekdays: average days in park in winter Weekend: average days in park in winter Average days in park in winter Weekdays: average minutes per day during weekdays in park in winter Weekend: average minutes per day in park in winter Average minutes in park in winter	

Relationships between green exposure measures and methods

To explore if the buffer and network methods produced similar values of green exposure, I ran pairwise correlations between each buffer and each network value. The results showed little correlation between the measures for the different green variables (Table 3.3, see buffer and buffer measures correlations and network and network correlations). Buffer and network methods have very low correlation (positive correlations average Pearson's R = 0.13 $\pm$ 0.13 SD, negative correlations average Pearson's R = -0.09 $\pm$ 0.08 SD), suggesting that they are measuring different kinds of exposure to green. This suggests that network- and buffer-based methods measure different types of exposure: living in proximity to green and green exposure on the immediate travel network. The only exception is NDVI buffer and network methods had a strong positive correlation which is not surprising given that NDVI data is stored as cells across the map area for both buffer and network methods (average Pearson's R = 0.74 $\pm$ 0.12 SD).

Table 3.3. The correlations between green exposure measures (Pearson's R) generated from a correlation matrix. Measures were compared across the three distances (50, 100 and 300m) between the buffer and network methods. Correlations between use and satisfaction with quality (NEST) and biodiversity (SR) are also presented.

	Positive correlations					Negative correlations				
	Average R2	SD	Min	Max	Range	Average R2	SD	Min	Max	Range
Buffer and buffer measures	0.33	0.22	0.00	1.00	1.00	-0.29	0.22	-0.89	0.00	0.89
Buffer and network	0.13	0.13	0.00	0.91	0.91	-0.09	0.08	-0.70	0.00	0.70
Network with network	0.09	0.30	-0.96	1.00	1.96	0.09	0.30	-0.96	1.00	1.96
Sr	0.19	0.11	0.03	0.37	0.34	NA	NA	NA	NA	NA
Nest	0.09	0.05	0.01	0.15	0.15	-0.03	0.04	-0.09	0.00	0.08
Land cover wood	0.44	0.13	0.21	0.59	0.37	NA	NA	NA	NA	NA
Land cover grass	0.16	0.16	0.01	0.46	0.45	NA	NA	NA	NA	NA
Land cover urban	0.05	0.05	0.01	0.10	0.09	-0.05	0.04	-0.09	0.00	0.09
NDVI	0.74	0.12	0.62	0.91	0.29	NA	NA	NA	NA	NA
Local area satisfaction and SR	0.03	0.02	0.02	0.05	0.03	-0.01	0.01	-0.02	0.00	0.02
Local area satisfaction and NEST	0.01	0.01	0.00	0.02	0.01	-0.02	0.02	-0.04	-0.01	0.04
Local area satisfaction and Use	0.11	0.08	0.05	0.16	0.11	NA	NA	NA	NA	NA
Local greenspace satisfaction And sr	0.03	0.02	0.00	0.07	0.06	NA	NA	NA	NA	NA
Local greenspace satisfaction And nest	0.03	0.01	0.02	0.04	0.02	NA	NA	NA	NA	NA
Local greenspace satisfaction And use	0.11	0.10	0.05	0.18	0.14	NA	NA	NA	NA	NA
Use and SR	0.03	0.02	0.02	0.02	0.00	NA	NA	NA	NA	NA
Use and NEST	0.04	0.03	0.03	0.03	0.00	NA	NA	NA	NA	NA

Analysis

The aim was to identify which measures of green exposure had the greatest explanatory power for health outcomes, with a specific emphasis on testing for additional explanatory power when using (i) network-based measures of green space exposure compared to buffer-based measures, and (ii) more nuanced measures of green space quality compared to satellite-derived measures. I applied the analysis below to two datasets: the full dataset that included all participants and a subset of the data where satisfaction and use of greenspace were also reported.

First, I ran a series of models with each health outcome as the response variable and set socio-demographic predictors associated with each health outcome with each green exposure measure in turn as the final predictor (see example below)(Table 3.4 shows the combination of variables available for each model). The model structure was determined by the response variable. For continuous variables (see **Table 3.1**), we used general linear models with Gaussian/normal error structures. For binary response variables (see **Table 3.1**), we used generalised linear models with binomial errors. This produced 81 models for each health outcome based on greenspace measures at 3 distances (50, 100 and 300 m) across 2 methods (buffer and network). For the BSB and BiB data sets VIFs for the models were below 2. For models run on the subset of the data contained terms with VIFs between 5 and 13.

Second, I compared the explanatory power of all models for each health outcome using Akaike's information criterion (AIC) and excluded any models with ΔAIC>2. This comparison allowed us to identify the green space variable that provided the most additional explanatory power to the model. Models were inspected visually for the normality, linearity and homoscedasticity using the check model in the performance R package (Lüdecke et al., 2021). Binomial models were checked for linearity through examination of a plot of each predictor against the logit of the response variable to ensure that there were no obvious deviations from linear relationships. To test whether the top model provided a meaningful improvement over simpler methods, I then compared the McFadden R^2 value of the model with the greatest explanatory power to the model with a buffer-based model of exposure and NDVI as the green space measure and a model including both the top variable and NDVI. The NDVI buffer model was considered to be the existing benchmark for environmental health research and any improvement in R^2 would indicate the additional value of using the more nuanced approaches. Note comparisons were always with models using the same exposure distance (for example if the top model was woodland cover at 50m this would be compared to NDVI buffer at 50m).

Example:

Health outcome ~ socioeconomic variable, demographic variables, relevant health and lifestyle variables depending on health outcome + ***X greenspace measure***

Table 3.4. Model variables. Each model would have a single health outcome, the same demographic and socioeconomic variables. Some additional health or lifestyle variables were included for health outcomes where data was available. All models would have a green exposure measure included. Use and satisfaction variables were added to models for each health outcome when available for that dataset.

	Health outcomes	Demographic, socioeconomic, lifestyle and health variables	Use and satisfaction	Green exposure measure
BSB Mother Child	Depression Anxiety Wellbeing BMI Birth weight	Age Ethnicity Education People they can count on General health Smoking while pregnant Alcohol while pregnant	Area satisfaction Greenspace satisfaction Greenspace use	Area Species richness User quality Land cover NDVI Street-level species richness Street-level quality Street-level green road type
BIB	BMI Blood pressure Gestational diabetes	Age Ethnicity Education Employed Weight	Greenspace use	
BIB Child (MeDALL)	Doctor diagnosed asthma Diagnosed with allergic rhinitis Ever had hay fever Ever been diagnosed with eczema/dermatitis Child ever had reactions to insect bites	General health Age Weight Managing financially Mother or father current smoker How often child where people smoke - weekdays How often child where people smoke - weekends Mother or father ever had asthma Mother or father ever had hay fever Mother or father ever had eczema House type Would you consider the house damp Is there mould within the dwelling		

3.4 Results

Greenspace in the BSB study area

Greenspace area covered 19.3% of the study area (431.6 ha of 2241.0 ha)(Figure 3.1, Table **3.5**). Most of the greenspaces in the study are amenity greenspaces (7270, 98.7% of greenspaces and 284.69 ha, 66.0% of total greenspace area). The remaining greenspaces were public parks (57, 0.8% of greenspaces and 108.6 ha, 25.2% of total greenspace area) or formal recreation (such as playing fields) (40, 0.5% of greenspaces and 38.3 ha, 8.9% of total greenspace area) (Figure 3.1). The average size of green space was 0.1 ha (± 0.6 SD, <0.01 – 30.9 ha). Only one greenspace within the study area had Green Flag Award status (an international benchmark standard for greenspace quality, (Green Flag Award, 2022)) and it had a NEST score of 114.9. The average NEST score was 66.9 (± 7.4 SD, 60.1 - 136.8) and the average species richness score was 9.0 (± 2.3 SD, 7.5 - 40.3) species (Figure 3.1). Urban land cover dominated the study area (Figure 3.2).

Street-level green

Almost half of the streets were categorised as grey, having no greenery (such as street trees or amenity grass; 49.7% [2330/4689]) (Figure 1,
Table **3.5**). Streets with green (grass only: 13.5% [635/4689]; trees only: 2.5% [166/4689]; grass and trees: 34.3% [1608/4689]) (Figure 3.1,
Table 3.5). The average species richness of the roads in the study area was low (2.6 ± 1.7 SD, 1 - 5), as was the user quality score of 59.1 (± 1.3 SD, 57.4 – 60.6 (Figure 3.1).

Table 3.5. Summary of greenspace and street-level green in the study area. Note that street type was used as the variable to determine street-level species richness and quality (NEST), therefore there are no averages.

Greenspace type	**Count**	**%**	**Total area (ha)**	**Percentage of study area greenspace**	**Percentage of total study area (ha)**	**Average size (ha)**	**SD**	**Min size ha**	**Max size ha**
Amenity	7270.0	98.7	284.79	66.0	12.7	<0.01	0.3	0.0	21.2
Urban park	57.0	0.8	108.6	25.2	4.9	1.9	5.8	0.0	30.9
Sports or recreation fields	40.0	0.5	38.3	8.9	1.7	1.0	1.8	0.0	9.6
Total greenspace	7367.0		431.6	-	19.3	-	-	-	-
Study Area		-	2241.0	-	100	-	-	-	-
Street-level green (n = 4689)	**Count**	**%**		**Biodiversity**	**NEST**				
Grey (no green)	2330.0	49.7		1.0	60.6				
Tree only	116.0	2.5		2.0	57.4				
Grass only	635.0	13.5		5.0	59.7				
Grass and Tree	1608.0	34.3		4.0	57.8				

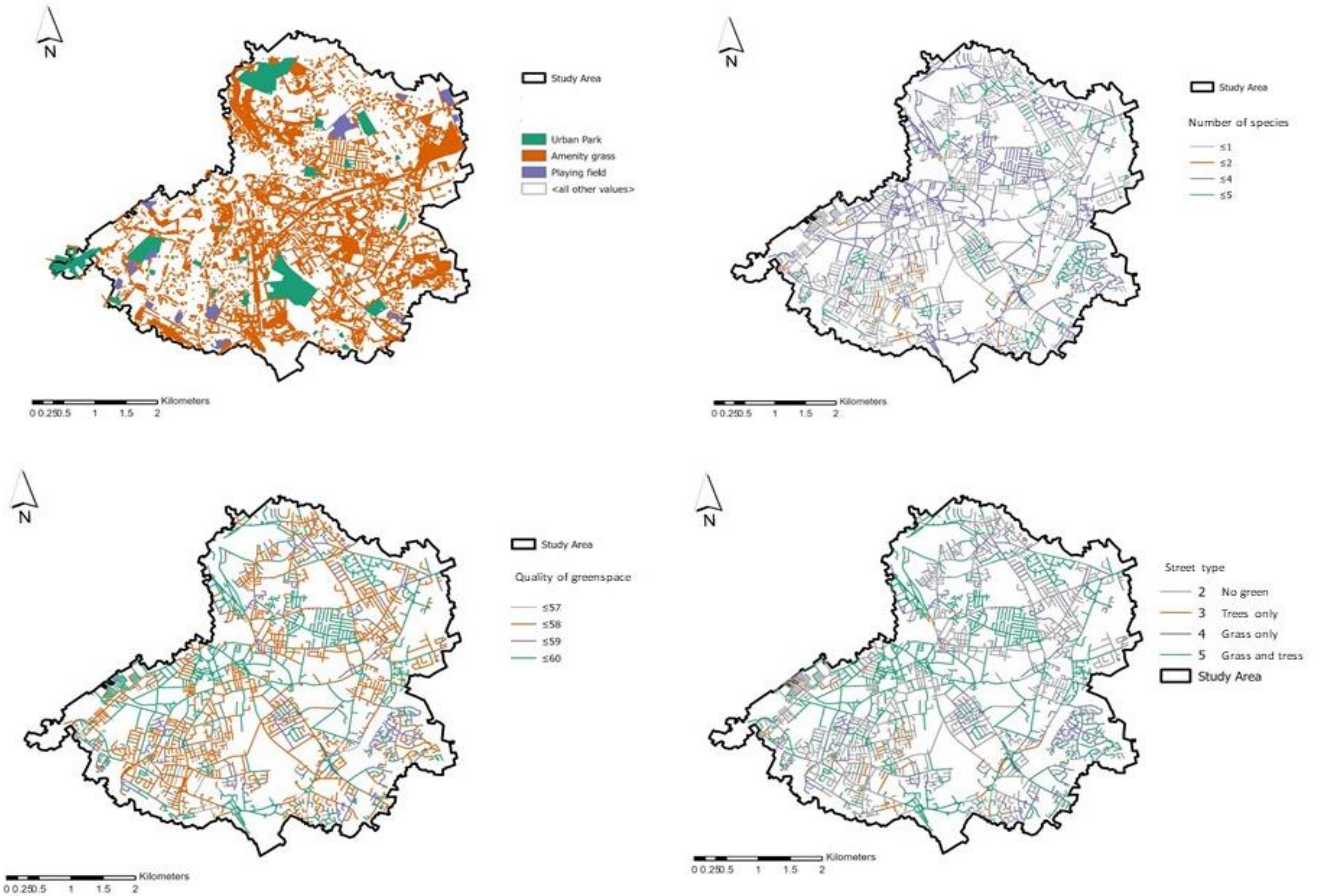


Figure 3.1. This displays the spread, type and size of greenspaces, the species richness of streets in the study area, the quality of greenspace on streets and the type of streets. Contains OS data © Crown Copyright OS Open Green Space and OS Open Roads (2023).

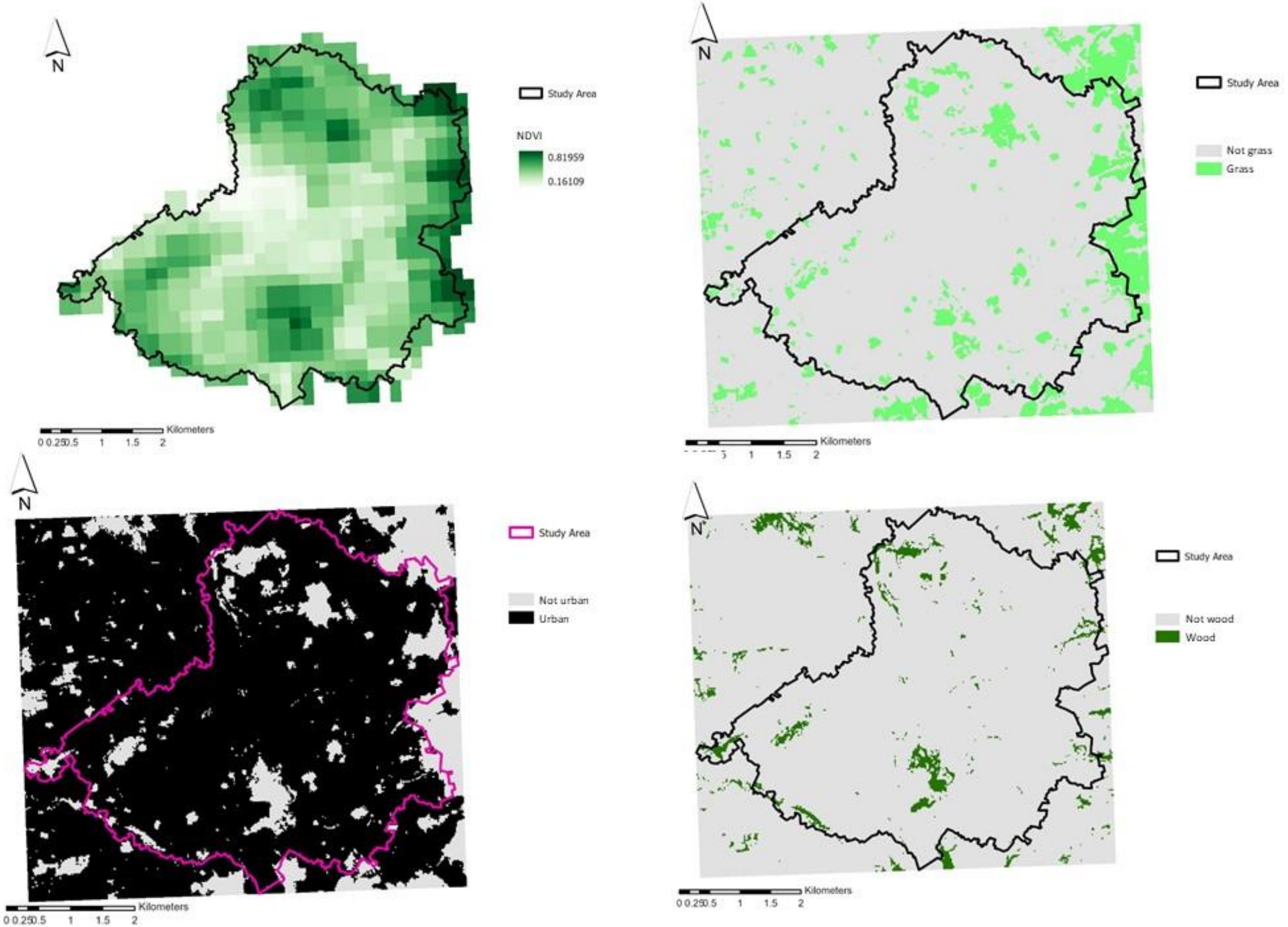


Figure 3.2. This displays the NDVI (Normalized Difference Vegetation Index) and land cover (grass, urban and woodland) for the study area (data from Didan, 2015; Morton et al., 2020).

Sample population: Better Start Bradford (BSB)

Socio-economic characteristics

The BSB data set includes 2644 mothers that live within the BSB area (Table 3.1). As this is survey data, most people answered all questions but there are some incomplete responses where participants did not answer all questions. In the summary data below, I make clear how many participants responded to each question (see full data summary in Table 3.6).

Most participants were of Pakistani heritage (61.9% [1628/2644]), which is representative of the pregnant population in the study area (Dickerson et al., 2016; Dickerson et al., 2022). The participants were in highly deprived areas (most deprived quartile Q1=84.2% [2000/2375], second most deprived quartile Q2=15.8% [375/2375]). A third perceived themselves as doing alright or living comfortably (38.8% [1020/2629] or 35.1% [922/2629], respectively). While almost a quarter perceived that they were just about getting by or finding it quite or very difficult to manage financially (22.1% [580/2629]). Thirty percent had high school equivalent education (30.6% [810/2644] had five or fewer GCSE (grades A-C) or equivalent). Most of the participants (all pregnant women) were unemployed at the time of survey collection (no: 66.3% [1745/2632]) but most had partners that were employed (85.6% [2130/2487]). The average household size was between two and four people (55.6% [1462/2626]). The majority did not have a garden (82.3% [2176/2644]).

Health characteristics

The majority of participants perceived themselves to have good, very good or excellent general health (76.4% [2019/2644]). However, of those for whom BMI data were available (n=935), the majority were overweight, obese or severely obese (35.7% [340/953], 26.4% [251/953], 12.5% [119/953] respectively).

Poor mental health was prevalent in the sample. The average wellbeing score for the sample was 21.82 ($\pm$ 11.39 SD) which equates to reasonable wellbeing (anything under 17 indicates depression and the maximum score is 35) and slightly lower than the national average of 23.61 ($\pm$=3.90 SD)(total n= 2644)(WEMWBS, 2011). Over a fifth of participants had some form of depression (mild, moderate, or severe) (29.8%, [577/1935]). Almost half of participants had had some form of anxiety (mild, moderate, moderately severe, or severe) (46.1%, [1138/2467]).

The majority of babies born in the BSB area had a healthy birthweight (71.4% [1790/2508]) with similar numbers having unhealthy-low or unhealthy-high birthweights (12.0% [300/2508] and 16.7% [418/2508], respectively).

Greenspace access, use and satisfaction

Participants had, on average, access to 526.2 m^2 (± 756.2 m^2) and 39726.6 m^2 (± 22456.8 m^2) within 50m and 300m of their home respectively. A small proportion have no greenspace within 50 or 100 m of their home (13.2% [350/2644], 0.1% [5/2644]), and all participants have greenspace within 300m of homes. When only including exposure to greenspace over 2 ha average access was 103.0 m^2 (± 467.0 SD) and 15303.0 m^2 (± 21315.4 m^2 SD) within 50 m and 300 m of their home respectively. The average user quality was low (58.0 ± 23.1 SD and 66.9 ± 1.5 SD) within 50 m and 300m.

The majority of the sample were satisfied (fairly or very) with their local areas (60.3% [1584/2629]) and their local greenspaces (57.3% [1505/2629]). For a subset of the sample that recorded use of greenspace, the majority visited their local park 2 to 4 times a week during summer (37.2% [303/814]) or once a week (21.1% [172/814]) but in the winter the majority of the sample visited their local greenspace less than once a month (65.5% [533/814]).

Sample population: Born in Bradford (BIB)

I used a subset of the BiB data by selecting only the people that lived within the BSB area for each data (baseline survey: 5240, see Table 3.1). If a person had more than one address, I averaged their green exposure across the multiple addresses to a single green exposure score for each green exposure measure. In the summary data below, I make clear how many participants responded to each question (see full data summary in Table 3.6).

Socio-economic characteristics

Most participants were South Asian (60.0% [2254/3752]) and the average age was 26.41 years (± 5.54 SD). Most of the participants (90.5% [3402/3758]) were in the most deprived quintile for the national measure of deprivation (index of multiple deprivation, IMD, 2010). Most participants had education with 5 or less GCSEs (or equivalent)(58.0% [2175/3748]). Most of the participants (the pregnant women) were not employed at the time of the survey (67.0% [2511/5239]). Household size was between one and five people for most participants (76.5% [2872/3756]).

Health characteristics

For mothers, most of the participants had a healthy MAP (96.3% [902.3/937] had MAP over 100 mm Hg) and a small percentage suffered from gestational diabetes (8.0% [333/4008]). On average, the mothers were slightly overweight based on the BMI categories (25.91 ± 5.77). For children, there was prevalence of the following allergies at age 4: asthma (9.3% [89/954]), hay fever (8.9% [85/870]), allergic rhinitis (3.3% [31/955]), eczema (20.6% [196/954]) and allergic reaction to insect bites (1.6% [15/954]).

Greenspace access and use

Participants had, on average, access to 632.5 m^2 (± 768.0 m^2 SD) and 41485.0 m^2 (± 23584.2 m^2 SD) within 50m and 300m of their home, respectively. A small proportion had no greenspace within 50 or 100 m of their home (9.3% [489/5240], 0.5% [25/25240]), and all participants have greenspace within 300m of their homes. When only including exposure to greenspace over 2 ha average access was 129.7 m^2 (± 490.0 SD) and 17207.8 m^2 (± 23112.2 m^2 SD) within 50m and 300m of their home respectively. The average user quality was low (59.3 ± 21.2 SD and 67.0 ± 1.4 SD) within 50 m and 300m.

A subgroup of the population (n=302) reported their time spent in green spaces (garden and public spaces). Most of these participants indicated that they had a garden (74.5% [225/302]). For public greenspaces, in the summer the most frequent use was two days per week (20.9% [63/302]) but there was variation (every day: 16.2% [49/302]; three days: 15.6% [47/302]; zero days: 8.9% [27/302]). In the summer, most participants spent over two hours across the week in the greenspaces (50.3% [152/302]) while 10% (31/302) did not spend any time at all. In winter, people used greenspaces less, with most not visiting at all (57.3% [173/302]) and spent less time there (over two hours: 9.3% [28/302], zero minutes: 57.6% [174/302]).

Table 3.6. The summary statistics of the demographic, socioeconomic and health and wellbeing outcomes for the study populations from Better Start Bradford and Born in Bradford.

Demographic and socioeconomic	**BSB** Category	Count	(%)	**BIB** Category	Count	(%)
Age	18 and under	35.0	1.3	18 and under	229.0	6.1
	19-25	646.0	24.5	19-25	1551.0	41.3
	26-30	880.0	33.4	26-30	1133.0	30.1
	30-40	1005.0	38.1	30-40	818.0	21.8
	over 40	69.0	2.6	over 40	27.0	0.7
	Total	2635.0	100.0	Total	3758.0	100.0

Ethnicity	South Asian	1628.0	61.9		South Asian	2255.0	60.1
	White British	303.0	11.5		White British	1234.4	32.9
	Other	699.0	26.6		Other	262.6	7.0
	Total	2630.0	100.0		Total	3752.0	100.0
Mother's highest education qualification	Degree or equivalent	785.0	29.7		Higher than A-level	768.3	20.5
	A levels or equivalent	303.0	11.5		A-level equivalent	539.7	14.4
	5 GCSE equivalent	308.0	11.6		5 GCSE equivalent	1162.0	31.0
	<5 GCSE equivalent	810.0	30.6		<5 GCSE equivalent	1012.0	27.0
	No qualifications	228.0	8.6		Other	209.9	5.6
	N/A	210.0	7.9		Don't know	56.2	1.5
	Total	2644.0	100.0		Total	3748.0	100.0
IMD Index of Multiple Deprivation (IMD) Decile (2019)	Most deprived quintile	2000.0	84.21	IMD (2010)	Most deprived quintile	3402.0	90.5
	Second most deprived quintile	375.0	15.8		Second most deprived quintile	287.0	7.6
					Third most deprived quintile	64.0	1.7
					Fourth most deprived quintile	3.0	0.1
					Fifth most deprived quintile	2.0	0.1
	Total	2375.0	100.0		Total	3758.0	100.0
Health outcome				Health outcome			
Body Mass Index (BMI)	Underweight	4.0	0.4	Body Mass Index (BMI)	Underweight	168.0	4.8
	Healthy weight	238.0	25.0		Healthy weight	1619.0	46.5
	Overweight	340.0	35.7		Overweight	969.0	27.8
	Obese	251.0	26.4		Obese	642.0	18.4
	Very obese	119.0	12.5		Very obese	86.0	2.5
	Sample	952.0	100.0		Sample	3484.0	100.0
	NA	1692.0			NA	1755.0	
	Total	2644.0			Total	5239.0	
Depression	None	1358.0	70.2	Gestational diabetes	No	3671.0	91.6
	Mild	380.0	19.6		Yes	337.0	8.4
	Moderate	122.0	6.3		Sample	4008.0	100.0
	Severe	75.0	3.9		NA	1231.0	
	Sample	1935.0	100.0		Total	5239.0	
	NA	709.0					
	Total	2644.0		Blood Pressure	Low MAP (<70)	47.0	5.0

Anxiety	None	1329.0	53.9
	Mild	776.0	31.5
	Moderate	255.0	10.3
	Moderately severe	78.0	3.2
	Severe	29.0	1.2
	Sample	2467.0	100.0
	NA	177.0	
	Total	2644.0	
General health	N/A	29.0	1.1
	Poor	115.0	4.3
	Fair	481.0	18.2
	Good	1210.0	45.8
	Very good	612.0	23.1
	Excellent	197.0	7.5
	Sample	2644.0	100.0
	NA	0.0	
	Total	2644.0	
Birthweight	Low	300.0	12.0
	Healthy	1790.0	71.4
	High	418.0	16.7
	Sample	2508.0	100.0
	NA	136.0	
	Total	2644.0	
Wellbeing	0-16.9 (possible depression)	561.0	21.2
	17.0-23.6 (lower than UK national average)	661.0	25.0
	>23.7 (higher than UK national average)	1422.0	53.8
	Sample	2644.0	
	NA	0.0	
	Total	2644.0	100.0

(Mean Arterial Pressure)			
	Healthy MAP (70-100)	860.0	91.8
	High MAP (>100)	30.0	3.2
	Sample	937.0	100.0
	NA	4302.0	
	Total	5239.0	
BiB children (MeDALL) - children <4 years old			
Asthma	No	865.0	90.7
	Yes	89.0	9.3
	Sample	954.0	100.0
	NA	4285.0	
	Total	5239.0	
Hay fever	No	870.0	91.1
	Yes	85.0	8.9
	Sample	955.0	100.0
	NA	4284.0	
	Total	5239.0	
Rhinitis	No	924.0	96.8
	Yes	31.0	3.2
	Sample	955.0	100.0
	NA	4284.0	
	Total	5239.0	
Eczema	No	758.0	79.5
	Yes	196.0	20.5
	Sample	954.0	100.0
	NA	4285.0	
	Total	5239.0	
Allergic reaction to insect bites	No	939.0	98.4
	Yes	15.0	1.6
	Sample	954.0	100.0
	NA	4285.0	
	Total	5239.0	

Table 3.7. Top models (within ΔAIC<2) for each health outcome. Green exposure measures, green use and satisfaction. Note Network (N), Buffer (B) and Non-Spatial (NS) methods for exploring surrounding greenspace.

		Green exposure	Green use	Greenspace satisfaction	Total
Better Start Bradford data	BMI	Lower with broad-leaved woodland cover 100m^{N}	No significant models	No significant models	
	Depression	Higher severity with higher species richness 300m^{N} Lower severity with no green streets 300m^{N} Higher severity with higher species richness on streets 300m^{N}		Lower severity with higher local area^{NS}	
	Anxiety	Higher severity with higher NDVI 300m^{N}		Lower severity with higher local area^{NS}	
	Wellbeing	Lower with higher species richness 300m^{B} Lower with higher NDVI 300m^{N}		Higher with local area satisfaction^{NS}	
	Low BW	Less likely with higher species richness 300m^{B}		No significant models	
	Healthy BW	Less likely with more streets with no green 50m^{N} More likely with grass only street 100m^{N} Less likely with more streets with no green 100m^{N}			
	High BW	More likely with more streets with no green 100m^{N} More likely with more streets with no green 50m^{N}			
Born in Bradford data	BMI	No significant models	No significant models	Data not available	
	Blood Pressure MAP	Higher with NDVI at 300mN			
	Gestational diabetes	More likely with streets with trees only 50m^{N} Less likely with streets with no green 50m^{N} More likely with streets with trees only 100m^{N}			
	Asthma	No significant models			
	Hay fever				
	Rhinitis				
	Eczema	More likely with higher NDVI 50m^{N} More likely with higher NDVI 100m^{B} More likely with higher NDVI 300m More likely with higher average greenspace >2ha 50m^{B} More likely with higher NDVI 50m^{B} More likely with total average greenspace >2ha 50m^{B}			
	Insect bites	No significant models			
Network (N)		16	0	2	18
Buffer (B)		7	0	1	8
Non-Spatial (NS)		N/A	0	4	4
Total		**23**	**0**	**7**	**30**

H1: Network measures of exposure better predict relationships between green space and health outcomes than buffer-based measures.

Buffer and network methods

A total of 16 of the 23 models where a greenspace term was a the predictor that had a high explanatory power of a health outcome were network-based measures and the remaining 7 were buffer-based measures. Models including network-based measures had the highest explanatory power for the following health outcomes: BMI, depression, anxiety, healthy birthweight, unhealthy-high birthweight, blood pressure, gestational diabetes, and eczema (Table 3.7). Models including buffer-based measures had the highest explanatory power for wellbeing and unhealthy-low birthweight.

H2: More nuanced measures of green space quality better predict relationships between green space and health outcomes than simpler measures based on NDVI.

NDVI, land cover and greenspace area

The models where NDVI was a predictor that had a high explanatory power of a health outcome included anxiety (higher severity with NDVI) wellbeing (lower with higher NDVI) blood pressure (higher with NDVI) and eczema (more likely with higher NDVI), having the highest explanatory power for anxiety, blood pressure and eczema (Table 3.7). The only model where land cover was a predictor that had a high explanatory power of a health outcome was where BMI was lower with broadleaved woodland cover; this was also the model with the highest explaining power for BMI. However, grass or urban land cover were not included in top models for any health outcomes (ΔAIC>2). Eczema was the only outcome with greenspace area as a predictor that had a high explanatory power of a health outcome but did not have the most explanatory power.

Quality

Out of the greenspace quality measures (user or biodiversity), only species richness had a high explanatory power for health outcomes (Table 3.7). Species richness had a positive correlation with the severity of depression (300m buffer and street-level). Higher species richness 300 m from their home was associated with lower wellbeing. However, babies were less likely to have an unhealthy-low birthweight with higher species richness within 300 m (buffer).

Street level green

A total of 12 of the 30 models where a green term had a high explanatory power of a health outcome were measures based on type of street. These were the following types of street exposure: grey streets (lower severity depression, less likely to have healthy birthweight, more likely with unhealthy-high birthweight, and less likely to have gestational diabetes), grass-only streets (more likely to have an unhealthy-high birthweight), tree-only streets (gestational diabetes more likely) and street-level species richness (higher severity depression)(Table 3.7). The following street-level measures had the greatest explaining power for the outcomes; grey streets for healthy birthweight and unhealthy-high birthweight, and tree-only streets for gestational diabetes. However, streets with trees and grass combined were not included in top models for any health outcomes (ΔAIC>2).

Comparing green measure explanatory power

There is low explanation of variation in the health and wellbeing outcomes from the green measures used in this study (R2= 0.02 – 0.30) (Table 3.8). When I compared novel and standard measures used in the literature (NDVI), I observed as small difference in explanatory power (an improvement in R^2 of 0.00 – 0.03). Depending on the research question, using traditional buffer NDVI methods may offer similar understanding compared to other greenspace measures. Similar results were found when comparing the explanatory power of alternative greenspace measures with the traditional measure of greenspace area (which is often readily available data, an improvement in R^2 of 0.02 – 0.30, Table 3.8). Although it is important to note that when NDVI was the model with the greatest explanatory power for anxiety, blood pressure and eczema, it was the network method of measuring NDVI but the comparisons above showed that buffer version was a good proxy.

Table 3.8. Shows the R2 value ranges for the top model of each health outcome compared to the traditional buffer method of NDVI or area matched at the same distance (e.g. 100 m).

Health Outcome	Green measure	Top model R^2 (reference used for differences)	NDVI R^2	Difference in R2 (difference between top model and NDVI)	Greenspace area R^2	Difference in R2 (difference between top model and area)	Difference in R2 Model including both top model predictor and NDVI	Difference	Difference in R2 Model including both top model predictor and NDVI	Difference
BMI	Broadleaved woodland 100m (network)	0.030	0.029	0.001	0.029	0.001	0.030	0.000	0.030	0.000
Depression	All green 300m species richness (network)	0.042	0.042	0.000	0.042	0.000	0.042	0.000	0.042	0.000
Anxiety	NDVI 300m (Network)	0.033	0.033	0.000	0.033	0.000	0.033	0.000	0.033	0.000
Wellbeing	All green 300m species richness (buffer)	0.027	0.027	0.000	0.027	0.000	0.027	0.000	0.027	0.000
Low BW	All green 300m species richness (buffer)	0.054	0.051	0.003	0.053	0.001	0.067	-0.013	0.066	-0.012
Healthy BW	street type - no green 50m (network)	0.046	0.043	0.003	0.044	0.002	0.047	-0.001	0.066	-0.020
High BW	street type - no green 100m (network)	0.065	0.061	0.003	0.061	0.004	0.064	0.001	0.064	0.001
Blood pressure	300m NDVI (network)	0.239	0.238	0.001	0.238	0.001	0.239	0.000	0.239	0.000
Eczema	50m NDVI (network)	0.138	0.138	0.000	0.136	0.003	0.144	-0.006	0.152	-0.014
Gestational diabetes	No green street 50m (network)	0.297	0.296	0.001	0.296	0.001	0.296	0.001	0.296	0.001
BMI	not significant (50m street type - no green) (network)	0.020	0.019	0.000	0.019	0.000	0.020	0.000	0.296	-0.276
Asthma	not significant (50m all green	0.166	0.158	0.009	0.157	0.009	0.173	-0.007	0.167	-0.001

	area avg) (buffer)									
Hay fever	not significant (100m street type - tree only) (network)	0.178	0.164	0.014	0.165	0.013	0.178	0.000	0.179	-0.001
Rhinitis	not significant 300m all green species richness avg (buffer)	0.162	0.134	0.028	0.134	0.027	0.163	-0.001	0.179	-0.017
insect bites	not significant (50m street type - tree only) (network)	0.115	0.094	0.022	0.107	0.008	0.119	-0.004	0.136	-0.021
	Min	**0.020**	**0.020**	**0.000**	**0.020**	**0.000**	**0.020**	**-0.013**	**0.027**	**-0.276**
	Max	**0.300**	**0.300**	**0.030**	**0.300**	**0.030**	**0.296**	**0.001**	**0.296**	**0.001**

H3: Greenspace satisfaction or use will better predict relationships between green space and health outcomes than spatial measures of green exposure.

Measures of greenspace use

Note that these are preliminary findings for a smaller subset of the data and so I urge caution when comparing with the wider results for the full sample used to explore spatial measures of greenspace exposure. When included in the models for a subset of the sample, greenspace use had no models as the top model (highest explanatory power of a health outcome) (Table 3.7). For the data where perceptions of greenspace were available (n= 2644), of the seven models where a term had a high explanatory power of a health outcome, four included perception, two were network-based greenspace measures, and one was buffered-based (Table 3.7). When perception measures were included in models for the subset, spatial greenspace measures were less important for explaining health outcomes. Models with local satisfaction measures had the highest explaining power for depression (lower severity with satisfaction), anxiety (lower with satisfaction), and wellbeing (higher with satisfaction)(Table 3.7). Satisfaction with local greenspaces was had a high explanatory power for unhealthy-high birthweight (less likely with higher satisfaction) but had lower explanatory power compared to the number of grey (no green streets) where unhealthy-high birthweights were more likely with more grey streets (Table 3.7). I did not find a significant correlation between quality (NEST) and satisfaction with the local area of greenspace(average R^2 = <0.01), but quality (NEST scores) were at the low to mid-range of the scale across the majority of the study area greenspaces (Table 3.3).

3.5 Discussion

In this study, I explore a diverse set of potential green space measures and how exposure might influence health outcomes. Note the focus of this chapter is the exploratory data analysis to compare different measures of greenspace rather than to identify associations with specific health outcomes. There were mixed results for the relationships between health outcomes and green exposure metrics or methods. I found that network-based measures of greenspace better predict relationships for health outcomes although buffer-based measures were better for predicting wellbeing and unhealthy-low birthweight. I found that NDVI was a predictor of health outcomes (anxiety, blood pressure and eczema), however other green exposure measures, species richness, broadleaved woodland cover and street-level green are better predictors for other health outcomes. However, the measure of the quality of greenspace for users (NEST score) was not a good predictor of health outcomes. When comparing NDVI to other measures of green exposure I found that using traditional buffer

NDVI methods can offer a similar understanding compared to other measures for certain research questions. I show that street-level measures of green or the lack of green are can have associations with for health outcomes (birthweight and gestational diabetes). I show that behavioural factors relating to greenspace exposure (greenspace use) were not the best predictors for health outcomes. I have preliminary results from a sub-sample that show that psychosocial factors such as satisfaction with the local area were good predictors for BMI and mental health (depression, anxiety and wellbeing) compared to the other measures in this study. This analysis shows that the relationship between greenspace and health outcomes requires additional analysis beyond traditional NDVI buffer measures to include measures of species richness and non-spatial measures relating to community perceptions of the spaces. Proximity to green can offer benefits but to maximise health and wellbeing benefits I show that perceptions of the local area, surrounding biodiversity and the presence or absence of street-level green should be integrated into the provision of green infrastructure.

These complex relationships have been found in previous populations in the UK, with health outcomes differing across multiple greenspace indicators (Mears, Brindley, Jorgensen, et al., 2020). Mears, Brindley, Jorgensen, et al. (2019), in a similar northern city in the UK, found a similar pattern and higher levels of poor health were associated with higher grass cover, which was predominantly amenity grassland with low user quality. While high accessibility to public greenspace was associated with poorer health and depression in a neighbouring UK city, Sheffield (Mears, Brindley, Jorgensen, et al., 2020). For context, Bradford and Sheffield are both industrial cities where historically greenspaces were implemented as public health measures for inner-city working classes living with higher density, air pollution and poor housing conditions (Crompton, 2013; Mears, Brindley, Maheswaran, et al., 2019). This may explain why poor health outcomes are present in areas with high greenspace access that converge with low incomes (Mears, Brindley, Jorgensen, et al., 2020).

Previous literature has found that people of lower socioeconomic status can receive greater health benefits from surrounding greenness and that green environments can help protect against income-related health inequalities, with these inequalities being lower in populations with higher residential greenness (Mitchell and Popham, 2008; Maas et al., 2009). There is also evidence that low-income, multi-ethnic communities greatly value greenspaces and recognise benefits for health and wellbeing, particularly for children (Cronin-de-Chavez et al., 2019). Therefore, it is important to maintain and or improve the existing greenspace resource to maximise health and wellbeing outcomes for these communities. To have effective interventions relating to green exposure there is a need to use approaches that look beyond general 'greenness' and unpack the other factors relating to green exposure and greenspace use such as the satisfaction, quality, biodiversity and greenspace-associated behaviour of these communities.

Health outcomes

Traditional metrics such as NDVI did not always have the largest explanatory power for these health outcomes. To recap, these traditional methods have explored exposure to greenspace in terms of the area of greenspace accessible (often excluding greenspace below a certain size) or measured the level of greenness using NDVI or land cover (Jarvis et al., 2020). Here I demonstrate that different measures of green may be better suited for exploring different health outcomes. Access to a greater area of greenspace has been found to have a positive relationship with health outcomes in other populations (White et al., 2013). However, models of greenspace area were not included in the list of top models (ΔAIC>2) for health outcomes. Instead, I found that other measures were more predictive for birthweight, contrasting a previous study of the area that found greenness to be the best predictive factor and that greenness promoted healthier birthweight (Dadvand, Wright, et al., 2014).

I show that although the traditional measure of greenness (NDVI), had significant relationships with anxiety (higher severity), wellbeing (lower), blood pressure (higher) and eczema (more likely), it did not for birthweight (contrasting with previous literature and the expected direction of relationships, see Dadvand, Wright, et al., 2014). Instead, the alternative measures of species richness and street type (no green) had greater explanatory power than NDVI for birthweight. However, the traditional metric of land cover was found to have a relationship with BMI (lower BMI with greater broadleaved woodland cover), supporting previous findings that good health was associated with broadleaf woodland, arable and horticulture and improved grassland (Wheeler et al., 2015). The diversity of trees in people's surroundings has been linked to lower obesity rates (for children 4-4 and 10-11) (Mears, Brindley, Baxter, et al., 2020). Density of trees can also reduce poor health and promote wellbeing (Mears, Brindley, Jorgensen, et al., 2019). For example, (Marselle et al., 2020) found that high density of street trees at 100 m around the home significantly reduced the probability of being prescribed antidepressants, particularly for individuals with low socio-economic status.

Although NDVI may not offer the greatest explanatory power for health and wellbeing outcomes, there was little additional explanatory power when using the alternative greenspace measures. The same pattern was found when comparing the network-based NDVI to buffer-based measures of NDVI. Here I show that traditional satellite-derived NDVI buffer methods can be used as a reasonable proxy for other measures of green exposure (such as network/street-level exposure or species richness). I would recommend exploring land cover measures of green or lack of green (such as grass, woods and urban land cover) as this is also usually readily available and could offer additional insight into which facet of green was promoting positive health outcomes and inform intervention design. Greenspace area was not included in the majority of top model lists in this study but is also readily available and should be included in future analyses as the size of greenspace can influence the use and quality of greenspaces which could impact other health and wellbeing outcomes, for example, physical activity. Similar to NDVI, area could be used as a proxy for exploring the population-level impact of green exposure and health outcomes but will neglect elements of greenspace quality and street-level interventions. However, compared to NDVI, other green measures could track changes in health and wellbeing outcomes in response to interventions that change the quality of greenspaces (such as increasing species richness or user quality) or street-level greenness (increasing street biodiversity through tree planting). This is key for maximising health benefits for communities where creating or expanding existing greenspace is not possible as the quality of the green will be the focus of interventions. Recording NDVI alongside alternative measures would be recommended as NDVI is widely used already in the literature, continued use of this measure will help with collating evidence and meta-analysis across studies (Rojas-Rueda et al., 2021).

Buffer vs street-level exposure (network)

I explored different methods of greenspace exposure and found that the traditional buffer methods were most appropriate for unhealthy-low birthweight (supporting (Dadvand, Wright, et al., 2014) and wellbeing. However, using a network-based method had associations with eight of the 13 health outcomes. Using a network-based approach might measure the lived exposure to greenspace and biodiversity through surrounding roads contrasting traditional buffer analysis that assume spillover of benefits from surrounding greenspace. In the study area, I observed negligible spillover of biodiversity (birds, bees or butterflies) from greenspaces to the surrounding streets, particularly as streets were usually grey or had small patches of amenity grass. However, there is evidence that smaller, high-quality greenspaces can offer important health and wellbeing benefits, particularly through regular *everyday* exposure (Natural England, 2010; Rupprecht and Byrne, 2014; Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Lovell et al., 2020; Dobson et al., 2021)(Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Lovell et al., 2020; Dobson et al., 2021)

I expanded on this network-based method further by including the street–level exposure to green elements (such as trees and biodiversity) alongside the impact of exposure to greenspaces through the road network. This approach builds on the traditional buffer method that limits analysis to greenspace over a certain size, as here I include all sizes of greenspaces. I show that these street-level metrics had associations with some health outcomes such as birthweight (for example less likely to be healthy birthweight with more grey streets) and gestational diabetes (more likely to suffer from gestational diabetes with tree-only streets but less likely with more grey streets; Table 3.7). Again, I show that traditional metrics and methods may neglect these important relationships with health outcomes. However, as noted above traditional NDVI could act as a proxy for these measures.

Quality of greenspaces and the wider environment

To explore a prevailing assumption in traditional greenspace studies, this study did not assume that all greenspace was equal and investigated if greenspace quality is related to health outcomes. I found that the measure of user quality (NEST) had no significant relationship with health outcomes. However, in a subset where satisfaction was included, there was a lower severity of depression and anxiety with higher satisfaction with the local area. This supports previous findings where satisfaction was more important for wellbeing than greenspace quality (McEachan et al., 2018). There may be elements of quality that were beyond those measured here by the NEST tool (access, recreation facilities, amenities, aesthetics (natural and non-natural), incivilities, safety and usability (Gidlow et al., 2018)). Alternatively, a greenspace may be of reasonable quality but cultural, personal or safety issues may prevent some groups from using that greenspace and maximising the health or wellbeing outcomes from a local greenspace (Seaman et al., 2010; Lo and Jim, 2010; Cronin-de-Chavez et al., 2019).

I showed that greenspace quality related to species richness may have a link to health outcomes and that not all greenspaces should be treated as equal. This supports previous findings that more diverse areas promote wellbeing, while lower wellbeing was found with a lack of biodiversity (Wood et al., 2018; Wyles et al., 2019; Cameron et al., 2020; Methorst et al., 2021; Knight et al., 2022). To the author's knowledge at time of writing this is the only study to explore the species richness and health outcomes at a population scale.

Perceptions and use of greenspace

I also show that psychosocial factors such as satisfaction with the local area are important to include in studies exploring greenspace and mental health or wellbeing outcomes. Models including these perception measures (satisfaction with the local area) were better at predicting health outcomes such as BMI, depression, anxiety, and wellbeing. This finding links to previous research that showed that satisfaction with green space was significantly associated with better wellbeing in children, but that this effect differed by race (McEachan et al., 2018). Previous studies have found that, despite recognising the value of visiting greenspaces, use was impacted by individual (such as not knowing where to go), contextual (poor weather), social (such as fear of anti-social behaviour) and built environment (such as poor accessibility or lack of toilets) determinants (Cronin-de-Chavez et al., 2019). The study took place in one of the UK's most deprived neighbourhoods where other problems associated with low income may add pressure on people's mental health and wellbeing that green exposure might not mitigate. The greenspaces themselves could also be of lower quality, which may act as a net disservice rather than an ecosystem service. The quality may influence if, when, and how people use green spaces meaning the health benefits are not maximised or there is the potential for negative impacts. For example, Birch et al. (2020) found that young people with poor mental health would avoid run-down parks as poor-quality parks can add to poor mood. Although this study did not find a correlation between low NEST and low satisfaction with local area of greenspace, the NEST scores implied most of the greenspaces were at the low to mid-range of the quality scale. Although some social factors can be enabling, such as positive interactions through social gatherings, other social factors can also limit the use and the associated benefits of greenspace exposure (Seaman et al., 2010; Lo and Jim, 2010).

Further research and limitations

The results offer novel insights into how different dimensions of green exposure influence health outcomes, as described above. However, this work also highlights key considerations for future research on this topic. Traditional buffer methods have limited value and could be expanded to network-based methods to explore lived exposure to green elements. To accompany this, street-level green elements (such as trees or lack of green; grey streets) should be included as there is little spill over of the benefits from greenspaces to surrounding streets, which buffer-based studies neglect. Traditional buffers aren't accurate for capturing the daily movement of individuals and therefore may exclude contact with greenspaces (particularly smaller informal spaces)(Laatikainen et al., 2018; Christensen et al., 2021; Christensen et al., 2022). Applying more detailed approaches to capturing movement in a space such as GPS-tracked movements (often available from phones are fitness devices) could add further detail beyond researcher or self-defined buffers (Kestens et al., 2018). However, buffer analysis is straightforward and less resource-intense compared to more detailed measures, so (Christensen et al., 2022) suggest that when buffers are the chosen method researchers should include at least one other key location as well as an individual's home (home and school or home and work) to be more representative of their daily movements. The use of Individualized Residential Exposure Models (IREM) could offer a more representative use of urban greenspace as it takes into account home location, visited places, frequency of visits, travel paths, and use of travel modes and weights given to most frequently visited and closer locations (Hasanzadeh et al., 2018; Laatikainen et al., 2018). In this study, the distance was for a 5 min walk so I did not assign weightings to the distances. Alternatively, the VERITAS questionnaire (Chaix et al., 2012) could be used, this uses interactive mapping and produces rapid geo-located data for where individuals visits and has been shown to offer a similar understanding as GPS-tracked activity (Kestens et al., 2018).

The quality of the greenspace should be explored alongside psychosocial elements of the local environment. Future analysis would explore the quality of streets for non-green amenities or facilities that may contribute to a high-quality built environment (using tools such as the Healthy Streets tool, (Saunders, 2022). These are associated with health outcomes (particularly mental health) but also influence the movement through the built environment and the use of greenspace.

The links between exposure and health outcomes could be carried out for greater distances such as 15-20 min walks. Previous studies have found benefits of greenness with up to 2000m (over a 20 min walk) from homes having a significant positive effect on physical health (Browning and Lee, 2017). This could inform decision-makers on how to maximise health benefits in denser developers, such as those proposed as '20-minute neighbourhoods' to help tackle climate change by reducing travel emissions. The furthest distance used in this study was equivalent to a 5-minute walk so all streets were given equal weighting, but future studies could explore weighting the greenspace measures a lower rating at further distances due to the lower exposure to this and the increased effort to get there.

3.6 Conclusion

Exposure to green can be measured in a variety of ways and using different methods (such as buffer or lived exposure through networks). I show that buffer and network analysis measure different types of exposure to green, which may influence health outcomes. There can be complex relationships between green measures and health outcomes, particularly in deprived communities in a historically industrial city. Different green measures might be best suited for particular health or wellbeing outcomes. Psychosocial measures such as satisfaction were found to have the most explaining power for some of the health outcomes in a smaller subset, showing that these should be included in studies exploring the impacts of the environment (built and perceived) on health outcomes as they may limit or maximise the health benefits from green exposure. Here, the reported use of greenspace had few associations with health.

Although there were mixed results for relationships between green metrics and methods with health outcomes, I show that ‘green’ in the built environment needs unpacking. The way green is measured (greenness NDVI/land cover, greenspace area, quality, perceptions of local greenspace) should be tailored to the type of health outcome to inform interventions. The green exposure measure should be expanded from traditional buffer methods to include lived exposure to green through network analysis and using a street-level measure of green elements, particularly as regular everyday contact with nature can offer health benefits for deprived urban communities. This could help maximise the health and wellbeing benefits received from green exposure. However, I show that traditional buffer NDVI measures can stand as a proxy for other measures of green exposure that are less readily available. Although only using NDVI methods as default may limit understanding of which facets of green exposure are linked to health outcomes and any associated interventions to maximise the benefits of ‘green’. I note that NDVI is widely used and recommend continued use of this measure alongside alternative measures as this will aid evidence collation and future meta-analysis.

This study took place in a biodiversity-poor and low-quality greenspace context, whereas comparison or exploration of health and wellbeing outcomes in less impoverished landscapes may offer further insight into which facets of green influence health outcomes. This study showed that NDVI was measuring different elements of green compared to the other measures such as species richness, area, and greenspace quality but this was only explored at the lower end of the scale. Therefore, I recommend continued research into ‘green’ exposure alongside traditional NDVI as a proxy to understand the mechanisms between green exposure, use, quality, perceptions and health and wellbeing.

4 A mixed-methods study of urban greenspace use and physical activity associated with natural and non-natural features

4.1 Abstract

Within urban areas, parks and other greenspaces are often treated as homogeneous patches of natural land. However, greenspaces are complex mosaics of natural and artificial features that each have different values for greenspace users. Here, I explore the links between physical activity and specific greenspace features (such as playgrounds and woods) by observing what, how and where people use different features. I used SOPARC (Systematic Observation of Play and Recreation in Communities) to measure the demographics of greenspaces users, how many there were using each feature and their level of physical activity. I had a special focus on 0-4 year-olds but captured data for all age groups. I collected data on 33 greenspaces in Bradford, UK. To understand the reasons behind patterns in use, I combined the observation data with participant-led walks of 18 female greenspace users (that care for or worked with children under 4 years old). These participants described their motivations for use and perceptions of the greenspace. There were 4020 park visitors observed, the majority adults (57%). Walking was the most common activity (63%). The playground was the most used feature (32%), features with trees were also popular (16 – 19%) but wooded areas were rarely used and only by adults (1%). However, participants from the guided walks described aspirations for using natural features but barriers such as safety, overgrown vegetation, litter and anti-social behaviour prevented them. The relationship between biodiversity and physical activity was unclear, but there were significantly more sedentary observations in areas with higher species richness. Through using a mixed-methods approach, I identified actions (such as cutting back overgrown vegetation) for urban greenspaces that could promote use and physical activity. The additional focus on children means that suggested changes could facilitate healthy habits and nature connection earlier in life.

4.2 Introduction

Greenspaces are a widely available resource for many communities (Besenyi et al., 2013) and can offer important benefits for health and wellbeing (Lovell et al., 2014; Lovell et al., 2020; Marselle et al., 2021). There is an opportunity to take both preventative and curative approaches to address poor health. Encouraging the use of greenspaces for physical exercise can help to address a growing issue of obesity in urban populations for adults and children. For example, lower obesity levels in children are associated with living closer to greenspaces

(Dadvand, Villanueva, et al., 2014). Creating healthy habits when in early years can help promote health in later life and greenspace is potentially freely available consistently across a lifetime (Marmot et al., 2020).

Alongside health benefits, greenspaces can also provide wellbeing benefits through their potential for restorative activities that are stimulating but not mentally taxing (Kaplan and Kaplan, 1989). A meta-analysis found that short-term exposure to the natural environment (as little as 15 minutes or 30 minutes) could reduce depressive mood (Shanahan et al., 2016; Roberts et al., 2019). A recent study in the UK found that good wellbeing was associated with spending 120 minutes (or more) in natural spaces, demonstrating that greenspaces can offer benefits beyond physical activity through experiencing a connection to nature (White et al., 2019).

Connection to nature and time in greenspaces also offer wider benefits beyond wellbeing, such as opportunities for experiential learning for children (Coates and Pimlott-Wilson, 2019). Play is important for both physical and emotional development (Whitebread, 2017; Islam et al., 2020). Play in the natural environment offers opportunities for children to have rich sensory experiences and memories and diversity in the natural environment plays an important role (Beery and Jørgensen, 2018). Outdoor play (particularly with an element of risk) promotes emotional resilience, social functioning and physical health and wellbeing in children (Brussoni et al., 2015; Islam et al., 2020). Alternatively, children with little contact with nature miss opportunities for physical, emotional and intellectual development (O'Brien and Murray, 2007). Childhood experience of nature also plays a strong role in adulthood such as influencing the frequency and types of visits to natural places, what greenspace features they use, displays of pro-environmental behaviours and connection to nature (Wells and Lekies, 2006; Thompson et al., 2008; Colléony et al., 2017). Greenspaces can therefore offer important opportunities for children's development through physical exercise, connection to nature, experience of biodiversity, and risk.

However, there are disparities in the availability of greenspace to urban residents, with individuals on lower incomes or of particular ethnicities having limited access, and further differences in how green spaces are used (McEachan et al., 2018; Ferguson et al., 2018). Therefore, there are disparities in the benefits received from greenspaces (Dadvand, Villanueva, et al., 2014; McEachan et al., 2018). Greenspaces may vary in the health benefits that they can offer due to their features and quality. Biodiversity is potentially one mechanism for this variation (Dallimer et al., 2012; Wheeler et al., 2015; Hoyle et al., 2017; Wood et al., 2018; Wyles et al., 2019; Cameron et al., 2020; Methorst et al., 2021; Knight et al., 2022). While low-quality green spaces with litter, anti-social behaviour or pests promote poor health outcomes or discourage use (Lyytimäki and Faehnle, 2009; McEachan et al., 2018; Cronin-de-Chavez et al., 2019; Kruize et al., 2020; Knobel et al., 2021). It is therefore important to explore the barriers and enablers to greenspace use in areas of low income and diverse ethnicities to understand how to address disparities and maximise greenspace benefits across society.

Greenspaces, particularly parks, are often considered homogeneous with little exploration of the differences in uses of the 'green' (such as open space with trees) and 'grey' features (such as playgrounds). To maximise benefits and support effective urban planning and greenspace management there is a need to understand which features are used and the benefits offered by each feature. Currently, there is a gap in the epidemiological literature in the understanding of the impact of the characteristics of greenspaces (including different features, quality, and biodiversity) on health outcomes (Kruize et al., 2020; Knobel et al., 2021).

In this study, I explore how parks with a range of natural and non-natural features are used, and how these features relate to physical activity. I also explore links between the quality of the greenspaces (including biodiversity) and use (including physical activity). I explicitly include greenspaces less than 0.5 ha and informal greenspaces (such as amenity grass roadside verges), which are often neglected in other analyses and have been shown to be used as a resource by community members (such as play spaces for children, dog walking, gardening, shortcuts, meeting places, relaxation and conservation areas)(Rupprecht and Byrne, 2014; Jarvis et al., 2020). The following research questions were explored:

1. What influences greenspace use?
2. Which natural 'green' and non-natural 'grey' features are used?
3. Is the physical activity level different in natural 'green' and non-natural 'grey' features?
4. What are the barriers and enablers for use of natural 'green' and non-natural 'grey' features?

4.3 Methods

Study setting

This study took place in the city of Bradford in Northern England in the United Kingdom. It has a population of over 500,000 people (2021 census, Bradford Metropolitan District Council, 2022a). Bradford is a diverse city with immigration predominantly from South Asian countries and a growing number of inhabitants from central and eastern European (Hall, 2013; Cronin-de-Chavez et al., 2019). This study takes place in three adjacent multi-ethnic electoral areas, which are some of the most diverse in Bradford (Kelly, 2015). These wards are also some of the most deprived when compared to the UK average on the index of multiple deprivation (IMD, 2019).

This study uses Greenspace Scotland's definition of greenspaces: 'any vegetated land or water within an urban area' (Greenspace Scotland, 2021). The study area has a variety of greenspaces, with a few large parks (over 10 hectares) and many pocket parks and informal greenspaces. This study took place in 2018 and 2019 across 33 greenspaces of varying sizes and quality that were spread evenly across the study area (Figure 4.1). These greenspaces were selected due to a) varying sizes, quality, and biodiversity, b) to collect baseline data for all the paired sites identified for the Better Start Bradford Better Place Project c) and to observe use across the whole study area.

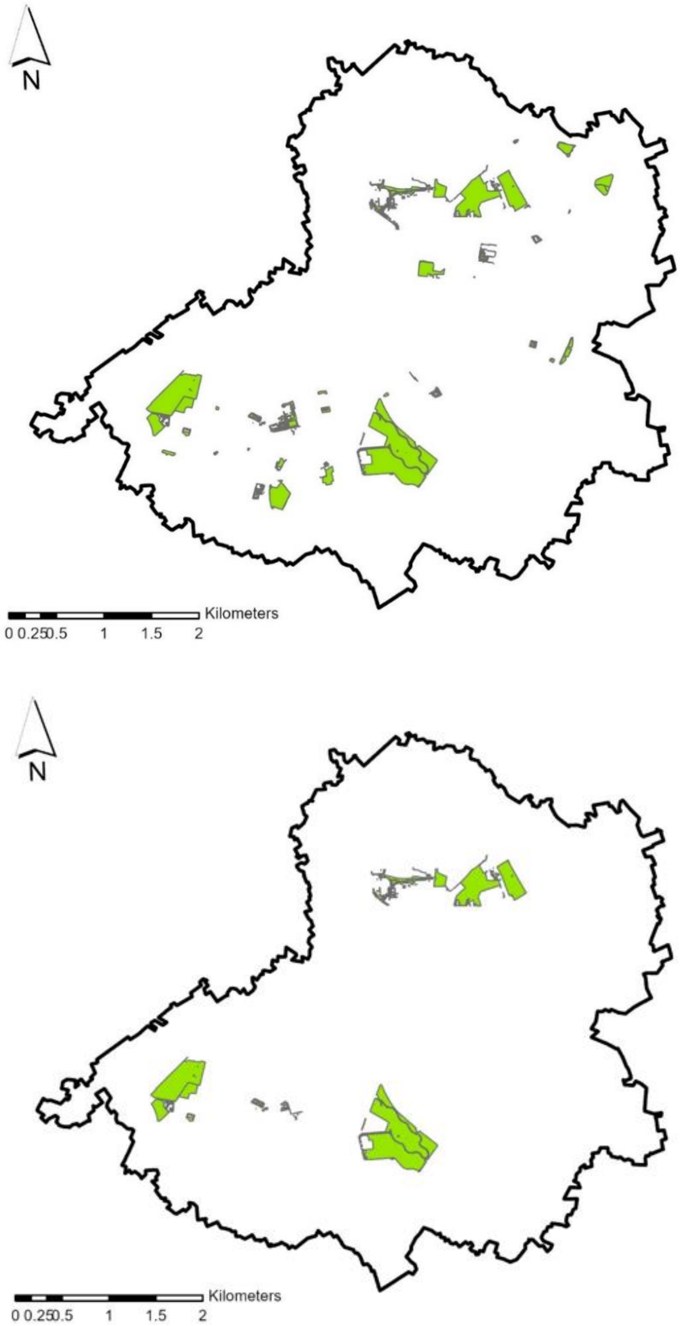


Figure 4.1. A map of greenspaces, showing (top) the sites used during the observational (SOPARC) study and (bottom) the subset of sites used in the qualitative (Our Voice) study which were selected by the participants. Contains OS data © Crown Copyright OS Open Green Space (2023).

Data collection

To understand what influences greenspace use, I collected data on the park quality, biodiversity, number and location of users and physical activity levels. I used participant-led guided walks to explore the barriers and enablers for use of natural 'green' and non-natural 'grey' features.

Park use and physical activity observation data

To capture greenspace use and physical activity across greenspace features I used a standardised observation tool (McKenzie and Cohen, 2006). The System for Observing Play and Recreation in Communities (SOPARC) is a validated tool to quantify park users and their activity (McKenzie and Cohen, 2006). Parks were visited at least twice, once on a weekday and a holiday day to mimic a weekend. The parks were divided into target areas following the method (McKenzie and Cohen, 2006).

Target areas in this study could be categorised into the following groups

1. Bowling greens
2. Court
3. Open space grass only
4. Open space grass and trees
5. Path – grass
6. Path – tree-lined
7. Path – water
8. Pitches
9. Playground infant (under 5 years)
10. Playground junior (over 5 years)
11. Skate park
12. Street – back street leading to/from greenspace
13. Tarmac play space
14. Wooded area

Every target area of each greenspace was observed by at least two coders three to four times (morning; 8.30 – 09.30, lunch; 12.00 – 13.00, afternoon; 15.00 – 16.00 and, evening; 17.00 – 18.00). However, some evening data collection was suspended due to safety concerns of the observers. Where possible the observation dates were kept consistent for each park to coincide with the previous year's observations (June – October). Standard SOPARC gender groupings (female, male), along with age (children: 0-4 years, 5-11 years, 12-16 years, adults: 17-20 years, 20-60 years, 60+ years) and ethnicity groups (White, South Asian, Black, Other). The standard method groups all children under 12 together so I adapted it to observe children in more detail (with the youngest being a few months old). Previous studies have also adapted the tool for observing children in more detail (Bocarro et al., 2009; Floyd et al., 2011). The observed activity was categorised as sedentary, moderate (e.g. walking) or moderate-to-vigorous physical activity. In some cases, specific detail of the type of physical activity performed was also recorded such as running, walking or sitting in a pushchair. A limitation of the data collection is that it is not possible to know how long users were using each feature. For example, people using paths may have been recorded while passing through the greenspace and may not be staying in the greenspace to walk a circuit, which has implications for the health benefits received from the greenspace itself. Future studies could also include the exercise equipment and picnic areas as separate targets areas as previous studies have found them to be important enabling features (Floyd et al., 2011; Cohen et al., 2012; Besenyi et al., 2013; Baran et al., 2014; Parra et al., 2019; Sami et al., 2020).

Greenspace quality including biodiversity

The Natural Environment Scoring Tool (NEST; Gidlow et al. 2018) was used to assess the presence/absence of features and condition of the environment to evaluate the overall quality of the parks and other green spaces. A higher score indicates a higher quality of amenities. The tool involves summing scores for each greenspace across eight categories: access, recreation facilities, amenities, aesthetics (natural and non-natural), incivilities, safety and usability. As the scoring is subjective, at least two researchers scored the park in each category to allow for an average score for each park to be calculated. Data collection took place in 2018 and 2019; there was no significant difference between the years, therefore scores were averaged for each greenspace.

To record birds, bees, butterflies and trees, transects were used that crossed each type of habitat in the greenspace (recording animals and plants 2.5 m either side) (Pollard et al., 1986; Fuller et al., 2007). Transects were carried out at times that would represent the park user experience of biodiversity (8.30 am – 5 pm). Transects were also conducted when there were appropriate conditions (sunny days above 13℃ or overcast days above 17℃ with winds below 5 on the Beaufort scale)(Carvell et al., 2017). Transects were the same route each year and selected by a route that passed through each habitat aiming to keep effort as consistent as possible across sites (approx. 20 min walk for each). Plants (excluding grasses) were identified through randomly placed quadrats (1m x 1m) in each habitat type (such as grass, scrub and woods) (5 repeats for each habitat type). Species richness (total number of species) was calculated for each taxon and as a total for each greenspace. Wildlife guides were used to identify pollinator species (such as the Big 8 Guide by Bumblebee Conservation Trust and the Big Butterfly Count ID chart by Butterfly Conservation). In 2019, these methods were also applied to a subset of SOPARC target areas in 8 of the 33 greenspaces. Point counts (15 min) of birds within the target area were carried out (two repeats at least 2 weeks apart). Biodiversity data collection was conducted at least twice two weeks apart in each year (2018, 2019 and 2020), for example, two transects per greenspace each year. The data from the repeats was averaged for each greenspace or target area.

Participant-led guided walks

To supplement the observation data participant-led walks that generate photo and audio data were used to understand the barriers and enablers to using different greenspace features (see, (King et al., 2016). The Discovery Tool Our Voice App provides the ability to take pictures of points of interest during a walk with each photo geo-located (King et al., 2016). For each photo, there is an option to record spoken comments about the point of interest and rate it as a good, bad, or indifferent issue. Walking methods are often employed in urban settings and can offer richer more representative data on people's relationship with their surrounding environment compared to sedentary methods or showing people pictures (Wylie, 2005; Pink, 2007; Bissell, 2009; Scott et al., 2009; Middleton, 2010; Evans and Jones, 2011; Pierce and Lawhon, 2015; Macpherson, 2016; Middleton, 2018). I build on this by expanding the walking methodology to urban greenspaces and combining this with data for these greenspaces (biodiversity and user quality). Participant-led walks were conducted between June and November 2018 and in June 2019 with parents, carers, or people that worked with 0-4-year-olds. Participants chose which greenspace they wanted to visit as long as it was within the study area (the three wards associated with Better Start Bradford (Figure 4.1). These walks were conducted individually or in pairs if the participants indicated they were more comfortable with paired walks. Participants were recruited through connections with nurseries and charities within the study area by advertising the study and a contact for researchers. Walks were then arranged at a time and date convenient to the participant(s). There was an agreement in place. There was an agreement in order to use the software, that it should only be used with the specific demographic (those that used urban greenspaces with children under four years of age). This aimed to fill a gap in the types of studies that had used the software. I recognise the limitations of recruitment leading to a specific demographic but argue that spaces designed to be safe for 0-4-year-olds are likely to be safe and accessible for wider society and early-year interventions are cost-effective and can have the potential positive life-long impacts (Marmot et al., 2020).

Analysis

To test the effect of park quality, species richness, size, weather and features on park use or number of park users observed at each physical activity level a generalized mixed model that took the park into account as a random effect was used. There was an acceptable level of collinearity (VIF: 1.0 – 4. 4)(James et al., 2013) but the data was over-dispersed (ratio: 6.2, $p<0.001$)(Thomas et al., 2017). Therefore, a zero-inflated Poisson regression model with the park as a random effect was used. The model was run on three groups of data: (i) for overall use including all demographic groups, (ii) on observations of use for each of the four age groups (0-4, 5-11, 12-16 and adults) and three activity levels (sedentary, moderate, vigorous) for the total observation data set, and (iii) for each activity level in each age group (sedentary 0-4s, moderate 0-4s, vigorous 0-4s and so on). Post-hoc tests explored the significant differences in observations between feature groups for overall use, as this was the only data set where the sample size was large enough to run post-hoc tests.

4.4 Results

Data characteristics

Greenspace characteristics

A total of 33 greenspaces spread equally across the study area were sampled (Figure 4.1). The spaces varied in size (0.01 - 32.60 hectares), quality (51.4 – 117.0), typology (urban park, functional amenity and formal recreation), and level of biodiversity (0.0 – 89.0 species) (Table 4.1). A total of 1264 observations (scans) of different park features were carried out. More observations were carried out in 2019 as 12 additional greenspaces were sampled. There were similar numbers of infant and junior playgrounds sampled (108 vs 138 scans).

User characteristics

A total of 4020 people were observed in this study. Similar numbers of females and males were observed (47.5 vs 52.5, n= 4020). The highest number of observed park users were between the age of 20 and 60, the largest grouping (n= 42.7%, n= 4020) (Table 4.1). The majority of observed park users were identified as South Asian (61.0%, n= 4020). Note the ethnicity was not collected as part of the Our Voice tool and cannot be reported numerically but participants included black, south Asian and white participants. Walking was the most observed activity level in the sample (63.3%, n= 4020). Observations were similar across the time of day but slightly higher in the afternoon (35.5%, n= 4020). There was an even split of people observed on a weekday and a holiday day (50.4 vs 49.6%, n= 4020). The majority of the observations were carried out in good weather (54.0%, n= 4020) (Table 4.2). A total of 18 photo-walks were carried out and 100% of the participants were female (age range: 24 – 38 years old).

Table 4.1. Summary of the demographic data of the observed sample, SOPARC target areas and the associated biodiversity and quality.

		SOPARC		Our Voice	
		count	**%**	**count**	**%**
Year	2018	1505	37.4	10	55.6
	2019	2515	62.6	8	44.5
Gender	F	1908	47.5	18	100.0
	M	2112	52.5	0	0.0
Age	0-4	406	10.1	0	0.0
	5-11	893	22.2	0	0.0
	12-16	444	11.0	0	0.0
	Adult	2277	56.6	18	100.0
	Total	4020			
Ethnicity	White	1325	33.0	N/A not collected	
	South Asian	2450	61.0	N/A not collected	
	Black	195	4.9	N/A not collected	
	Other	42	1.0	N/A not collected	
Typology	Urban Park	18	54.5	4	57.1
	Functional/amenity	12	36.4	2	28.6
	Formal Recreation	3	9.09	1	14.3
Target Area	Bowling greens	3	2.4		
	Court	13	10.4		
	Open space grass	12	9.6		
	Open space grass with trees	27	21.6		
	Path – grass	5	4		
	Path – tree-lined	18	14.4		
	Path – water	1	0.8		
	Pitches	9	7.2		
	Playground infant	9	7.2		
	Playground junior	13	10.4		
	Skate park	1	0.8		
	Street – back street	2	1.6		
	Tarmac play space	8	6.4		
	Wooded area	4	3.2		
NEST	Min	51.4		64.2	
	Max	117.0		107.4	
	Average	75.3		83.2	
	SD	15.9		16.6	
SR	Min	0.0		12.0	
	Max	89.0		63.0	
	Average	25.7		40.9	
	SD	21.0		20.1	
Area	Min	0.00		0.00	

Max	0.30	0.16
Average	0.03	0.05
SD	0.06	0.06

Table 4.2. Summary statistics for the observation data, when and level of activity.

		Total observations		0-4yrs		5-11yrs		12-16yrs		Adults	
		count	%	count	%	count	%	count	%	count	%
Activity level	Sedentary	962	24	147	36	100	11	125	28	590	26
	Walking	2546	63	212	52	565	63	223	50	1546	68
	Vigorous	512	13	47	11	228	26	96	22	141	6
Time of day	Morning	612	15								
	Lunch	880	22								
	Afternoon	1428	36								
	Evening	1100	27								
Day	Holiday	1995	50								
	Weekday	2025	50								
Weather	Poor	192	5								
	Reasonable	1657	41								
	Good	2171	54								

1. *What influences greenspace use?*

Weather, quality and size

Higher numbers of park users were observed in good or reasonable weather compared to poor weather and in parks with higher user quality (z= 3.04, p <0.001, z = 2.30, p <0.001 and z= 6.27, p= 0.001). There was no significant difference between the observations for good or reasonable weather. Reasonable or good weather increased the number of park users observed in each activity level (sedentary, walking and vigorous), except there was no significant impact on vigorous observations with good weather (Table 4.3). Park quality had a similar impact on park users, with more sedentary and walking observations in higher quality parks but there was no impact on vigorous observations (z= 1.66, p= 0.09; z= 1.84, p= 0.07 and z= 1.16, p= 0.25). The size of the park did not influence the number of observations (z = 1.36, p

= 0.18) or activity levels observations (z=-1.31, p = 0.19; z= 0.02, p= 0.98, and z= 0.03, p=0.98) (Table 4.3).

Features

Feature type had a significant effect on observations. Post-hoc tests showed that fewer sedentary park users were observed on courts, pitches, woods, and open spaces (grass, grass and trees)(Table 4.4). More walking park users were observed in junior playgrounds (Table 4.4). Fewer park users were observed walking in infant playgrounds and woods (Table 4.4). Park users were observed taking part in vigorous activity in courts, pitches, playgrounds (infant and junior), skate parks, open spaces (grass and grass with trees) and paths (tree-lined and water-lined(Table 4.4).

Biodiversity

On a park level, the total species richness of the park did not significantly affect the numbers of park users observed (z= -1.50, p= 0.13) (Table 4.3). However, more sedentary park users were observed in greenspaces with higher tree species richness (z=2.52, p=0.01) (Table 4.5). Bird and plant species richness had no significant impacts on the number of people observed in an area or their activity level (Table 4.5). An overall summary of what influences activity levels on a park level can be found in Table 4.6. At a target area level (comparing areas within parks see Table 4.1), there were fewer walking and vigorous observations in areas with higher total species richness (z=-2.72, 0.018, z=-1.77, P=0.08, Table 4.7). Higher tree species richness was significantly associated with higher total observations in an area (z= 3.59, p=<0.001) but no significant relationship with activity level was found (Table 4.7). However, there were fewer total and walking observations in areas with higher plant species richness (z= -3.215, p= <0.001, z=-2.88, p= 0.004) (Table 4.7). Bird species richness and abundance had no significant relationship with total observations or activity levels (Table 4.7).

Table 4.3. Summary of what influenced observations on a park level.

	Total		**Sedentary**		**Walking**		**Vigorous**	
	Chisq	P	Chisq	P	Chisq	P	Chisq	P
Quality (NEST)	4.93	**0.03**	2.74	0.10	3.39	0.07	1.34	0.25
Greenspace Area (km^2)	0.21	0.64	1.72	0.19	0.00	0.98	**0.00**	0.98
Species richness	0.15	0.70	3.82	**0.05**	0.00	0.97	0.10	0.75
Weather	23.50	**<0.01**	48.65	**<0.01**	10.87	**<0.01**	4.00	0.14
Feature	540.18	**<0.01**	125.30	**<0.01**	249.86	**<0.01**	83.60	**<0.01**

Table 4.4. Summary statistics for what influences total observations and the number of people observed at each activity level.

	Total		Sedentary		Walking		Vigorous	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Intercept	-0.348	(-2.791, 2.095)	-4.221*	(-7.637, -0.805)	-0.835	(-4.175, 2.506)	-2.578	(-9.169, 4.013)
Quality (NEST)	0.024*	(0.003, 0.044)	0.022.	(-0.004, 0.047)	0.027.	(-0.002, 0.056)	0.032	(-0.022, 0.087)
Greenspace Area (log area km))	-0.052	(-0.273, 0.169)	-0.234	(-0.584, 0.116)	0.004	(-0.291, 0.298)	0.01	(-0.609, 0.629)
Species richness	0.003	(-0.013, 0.019)	0.02.	(0, 0.039)	0.0005	(-0.021, 0.022)	0.007	(-0.035, 0.049)
Weather – Good*	0.403***	(0.232, 0.575)	2.015***	(1.432, 2.598)	0.327**	(0.132, 0.522)	0.495	(-0.127, 1.117)
Weather – Reasonable*	0.309***	(0.14, 0.479)	1.818***	(1.234, 2.402)	0.275**	(0.084, 0.466)	0.6.	(-0.02, 1.219)
Bowling greens#	-0.965***	(-1.27, -0.66)	-0.324	(-0.853, 0.205)	-0.609**	(-1.063, -0.154)	-2.428***	(-3.738, -1.118)
Court#	-0.616***	(-0.756, -0.476)	-0.921***	(-1.25, -0.592)	-0.548***	(-0.747, -0.349)	-0.122	(-0.457, 0.213)
Open space grass#	-0.77***	(-1.091, -0.449)	-1.307***	(-1.887, -0.727)	-0.723***	(-1.148, -0.299)	-1.876**	(-3.14, -0.612)
Open space grass and trees#	-1.036***	(-1.147, -0.925)	-0.851***	(-1.082, -0.62)	-0.855***	(-0.997, -0.712)	-0.944***	(-1.302, -0.585)
Path (grass) #	-1.027***	(-1.262, -0.792)	-0.708**	(-1.146, -0.269)	-0.647***	(-0.972, -0.323)	-2.066**	(-3.32, -0.812)
Path (tree-lined)#	-0.833***	(-0.944, -0.721)	-0.755***	(-0.972, -0.539)	-0.706***	(-0.851, -0.562)	-0.772***	(-1.125, -0.42)
Path (water) #	-0.583***	(-0.835, -0.332)	-0.51	(-1.128, 0.108)	-0.549***	(-0.853, -0.244)	-0.022	(-0.842, 0.797)
Pitches#	-0.806***	(-0.96, -0.651)	-0.886***	(-1.297, -0.475)	-0.654***	(-0.85, -0.458)	-0.293	(-0.721, 0.135)
Playground (infant under 5 years old)#	-1.075***	(-1.282, -0.868)	-0.62**	(-1.014, -0.226)	-1.193***	(-1.471, -0.915)	-0.59*	(-1.171, -0.009)
Skate park#	-0.759*	(-1.378, -0.139)	-1.579*	(-3.015, -0.143)	-1.54*	(-2.756, -0.324)	1.109*	(0.064, 2.154)
Street back street#	-1.503*	(-2.91, -0.095)	-18.27	(-4643.87, 4607.33)	-0.727	(-2.412, 0.958)	-18.45	(-7742.81, 7705.91)
Tarmac play space#	-0.866***	(-1.085, -0.648)	-0.023	(-0.444, 0.398)	-0.9***	(-1.201, -0.6)	-2.416***	(-3.385, -1.447)
Woods#	-2.791***	(-3.418, -2.163)	-2.804***	(-3.724, -1.884)	-2.871***	(-3.588, -2.154)	-25.37	(-36442.17, 36391.43)

*Reference level = poor weather; # Reference level = playground junior (5-11 years)

Table 4.5. Summary of the influence of species richness (bird, tree and plant) on the number of people observed and activity levels of those observed in the greenspace.

		Total		Sedentary		Walking		Vigorous	
		Chisq	P	Chisq	P	Chisq	P	Chisq	P
Bird	Quality (NEST)	5.86	**0.02**	3.32	0.07	3.75	0.05	1.46	0.23
	Greenspace Area (km^2)	0.82	0.36	0.03	0.86	0.27	0.61	0.03	0.87
	Species richness	0.90	0.34	0.08	0.77	0.56	0.46	0.87	0.35
	Weather	23.57	**<0.001**	48.89	**<0.001**	10.90	**<0.001**	11.83	**<0.001**
	Feature	540.68	**<0.001**	120.37	**<0.001**	250.63	**<0.001**	133.85	**<0.001**
Tree	Quality (NEST)	2.94	0.086	0.906	0.341	2.292	0.13	0.828	0.363
	Greenspace Area (km^2)	0.656	0.418	2.078	0.149	0.034	0.855	0.002	0.968
	Species richness	1.321	0.25	6.359	**0.012**	0.268	0.604	0.338	0.561
	Weather	23.342	**<0.001**	48.401	**<0.001**	10.867	**0.004**	4.029	0.133
	Feature	541.694	**<0.001**	125.957	**<0.001**	250.516	**<0.001**	84.138	**<0.001**
Plant	Quality (NEST)	5.775	**0.016**	3.529	0.06	3.71	0.054	1.693	0.193
	Greenspace Area (km^2)	0.014	0.907	0.2	0.655	0.021	0.886	0.231	0.631
	Species richness	0.395	0.53	1.162	0.281	0.126	0.722	0.433	0.511
	Weather	23.363	**<0.001**	48.864	**0**	10.811	**0.004**	3.944	0.139
	Feature	538.537	**<0.001**	122.486	**0**	249.388	**<0.001**	81.504	**<0.001**

*Reference level = poor weather; # Reference level = playground junior (5-11 years)

Table 4.6. A summary of what influences activity levels on a park level.

	Less Likely	**More Likely**
Sedentary	courts, open space – (grass, grass & trees), pitches, woods	Good and reasonable weather, NEST, species richness, tree species richness
Walking	playground - infants, woods	Good and reasonable weather, playground – junior, NEST
Vigorous	N/A	courts, open space- grass & trees, paths (grass, tree, water), pitches, playground (infant & junior), skate park, reasonable weather

Table 4.7. Summary of the influence of target level (areas in parks, Table 4.1) species richness (total, bird, tree and plant) on the total observations and activity levels of those observed in target areas.

	Total observations		**Sedentary**		**Walking**		**Vigorous**	
	Z	P	Z	P	Z	P	Z	P
					Total Species richness			
Intercept	-1.76	0.08	-1.75	0.08	-1.61	0.11	-1.61	0.11
Quality (NEST)	5.08	**<0.01**	0.59	0.56	3.39	**<0.01**	2.27	**0.02**
Total species richness	-1.29	0.20	-0.99	0.32	-2.37	**0.02**	-1.77	0.08
Weather Good*	1.88	0.06	4.96	**<0.01**	-0.17	0.86	0.00	1.00
Weather Reasonable*	1.22	0.22	4.36	**<0.01**	0.65	0.52	0.51	0.61
Open space grass#	-0.01	0.99	0.00	1.00	-0.01	1.00	0.00	1.00
Open space grass and trees#	1.59	0.11	2.08	**0.04**	3.00	**<0.01**	-1.26	0.21
Path (grass)#	1.34	0.18	1.53	0.13	2.31	**0.02**	0.46	0.65
Path (tree-lined)#	4.17	**<0.01**	1.34	0.18	3.52	**<0.01**	2.23	**0.03**
Pitches#	3.89	**<0.01**	0.78	0.43	3.55	**<0.01**	0.42	0.67
Playground (infant < 5 years old) #	9.08	**<0.01**	4.53	**<0.01**	7.29	**<0.01**	2.50	**0.01**
Tarmac play space	1.76	0.08	1.36	0.18	1.93	**0.05**	-0.46	0.64
Woods	-3.07	**<0.01**	-2.26	**0.02**	-1.93	**0.05**	0.00	1.00
					Bird species richness			
Intercept	-2.44	**0.01**	-1.18	0.24	-1.97	**0.05**	-1.70	0.09
Quality (NEST)	5.33	**<0.01**	0.16	0.88	3.38	**<0.01**	2.26	**0.02**
Bird species richness	1.67	0.09	-0.56	0.58	0.61	0.54	-0.10	0.92
Weather Good*	1.93	**0.05**	4.98	**<0.01**	-0.06	0.96	0.12	0.91
Weather Reasonable*	1.13	0.26	4.34	**<0.01**	0.56	0.57	0.43	0.66
Open space grass#	-0.01	0.99	0.00	1.00	-0.01	1.00	0.00	1.00
Open space grass and trees#	0.96	0.34	1.87	0.06	1.93	**0.05**	-2.79	**0.01**
Path (grass)#	0.40	0.69	1.25	0.21	0.87	0.38	-1.64	0.10
Path (tree-lined)#	3.90	**<0.01**	1.19	0.23	3.10	**<0.01**	1.99	**0.05**
Pitches#	3.85	**<0.01**	0.76	0.45	3.82	**<0.01**	0.09	0.93
Playground (infant under 5 years old)#	10.51	**<0.01**	4.71	**<0.01**	6.98	**<0.01**	1.71	0.09
Tarmac play space#	1.70	0.09	1.01	0.31	1.39	0.16	-0.84	0.40
Woods#	-3.46	**<0.01**	-2.72	**0.01**	-2.62	**0.01**	0.00	1.00
					Bird Abundance			
(Intercept)	-2.49	**0.01**	-1.10	0.27	-2.17	**0.03**	-1.69	0.09
Quality (NEST)	5.44	**<0.01**	0.05	0.96	3.66	**<0.01**	2.26	**0.02**
Bird abundance	1.87	0.06	-0.81	0.42	1.11	0.27	-0.17	0.87
Weather Good*	1.95	**0.05**	4.97	**<0.01**	-0.05	0.96	0.11	0.91
Weather Reasonable*	1.16	0.25	4.34	**<0.01**	0.57	0.57	0.43	0.67
Open space grass#	-0.01	0.99	-0.01	1.00	-0.01	0.99	0.00	1.00
Open space grass and trees#	1.20	0.23	1.79	0.07	2.05	**0.04**	-2.86	**<0.01**
Path (grass)#	0.43	0.67	1.27	0.20	0.87	0.38	-1.68	0.09
Path (tree-lined)#	3.83	**<0.01**	1.21	0.23	3.05	**<0.01**	1.99	**0.05**
Pitches#	3.70	**<0.01**	0.81	0.42	3.69	**<0.01**	0.10	0.92
Playground (infant under 5 years old)#	10.56	**<0.01**	4.68	**<0.01**	7.10	**<0.01**	1.70	0.09

Tarmac play space#	1.82	0.07	0.92	0.36	1.53	0.13	-0.85	0.39
Woods#	-3.38	**<0.01**	-2.77	**0.01**	-2.54	**0.01**	0.00	1.00
Tree Species richness								
Intercept	-3.31	**<0.01**	-1.34	0.18	-2.35	**0.02**	-1.87	0.06
Quality (NEST)	6.15	**<0.01**	0.34	0.73	3.80	**<0.01**	2.39	**0.02**
Tree Species richness	3.59	**<0.01**	-0.28	0.78	1.51	0.13	0.63	0.53
Weather Good*	2.00	**0.05**	4.99	**<0.01**	-0.03	0.98	0.17	0.87
Weather Reasonable*	1.33	0.18	4.34	**<0.01**	0.64	0.52	0.47	0.64
Open space grass#	-0.01	0.99	-0.01	1.00	-0.01	0.99	0.00	1.00
Open space grass and trees#	0.88	0.38	1.85	0.06	1.91	0.06	-2.87	**<0.01**
Path (grass)#	0.12	0.90	1.20	0.23	0.77	0.44	-1.91	0.06
Path (tree-lined)#	4.97	**<0.01**	0.99	0.32	3.40	**<0.01**	2.05	**0.04**
Pitches#	4.55	**<0.01**	0.68	0.50	4.12	**<0.01**	0.17	0.86
Playground (infant under 5 years old)#	10.89	**<0.01**	4.76	**<0.01**	7.20	**<0.01**	1.82	0.07
Tarmac play space#	2.39	**0.02**	1.00	0.32	1.71	0.09	-0.67	0.50
Wood#	-3.29	**<0.01**	-2.69	**0.01**	-2.50	**0.01**	0.00	1.00
Plant species richness								
Intercept	-2.87	**<0.01**	-1.67	0.09	-2.72	**0.01**	-1.93	**0.05**
Quality (NEST)	6.08	**<0.01**	0.62	0.54	4.47	**<0.01**	2.50	**0.01**
Plant species richness	-3.22	**<0.01**	-0.15	0.88	-2.88	**<0.01**	-0.61	0.54
Weather Good*	1.89	0.06	5.00	**0.00**	-0.12	0.91	0.14	0.89
Weather Reasonable*	1.22	0.22	4.34	**0.00**	0.63	0.53	0.45	0.65
Open space grass#	-0.01	0.99	-0.01	1.00	-0.01	1.00	0.00	1.00
Open space grass and trees#	2.88	**<0.01**	1.61	0.11	3.32	**<0.01**	-1.88	0.06
Path (grass)#	2.76	**0.01**	0.96	0.34	2.67	**0.01**	-0.54	0.59
Path (tree-lined)#	4.94	**0.00**	1.15	0.25	4.00	**<0.01**	2.07	0.04
Pitches#	4.32	**0.00**	0.71	0.48	4.10	**<0.01**	0.27	0.79
Playground (infant under 5 years old)#	9.38	**0.00**	3.64	**<0.01**	6.97	**<0.01**	1.44	0.15
Tarmac play space#	2.84	**0.00**	1.07	0.29	2.56	**0.01**	-0.54	0.59
Woods#	-2.34	**0.02**	-2.45	**0.01**	-1.46	0.14	0.00	1.00

*Reference level = poor weather; # Reference level = playground junior (5-11 years)

2. *Which natural 'green' and non-natural 'grey' features are used?*

Non-natural features

The greatest number of people was observed in playgrounds (25.8%, n= 4020). Post-hoc tests showed that significantly more people were observed in junior playgrounds (designed for children older than 5 years) than in any of the other park features (p <0.001)(

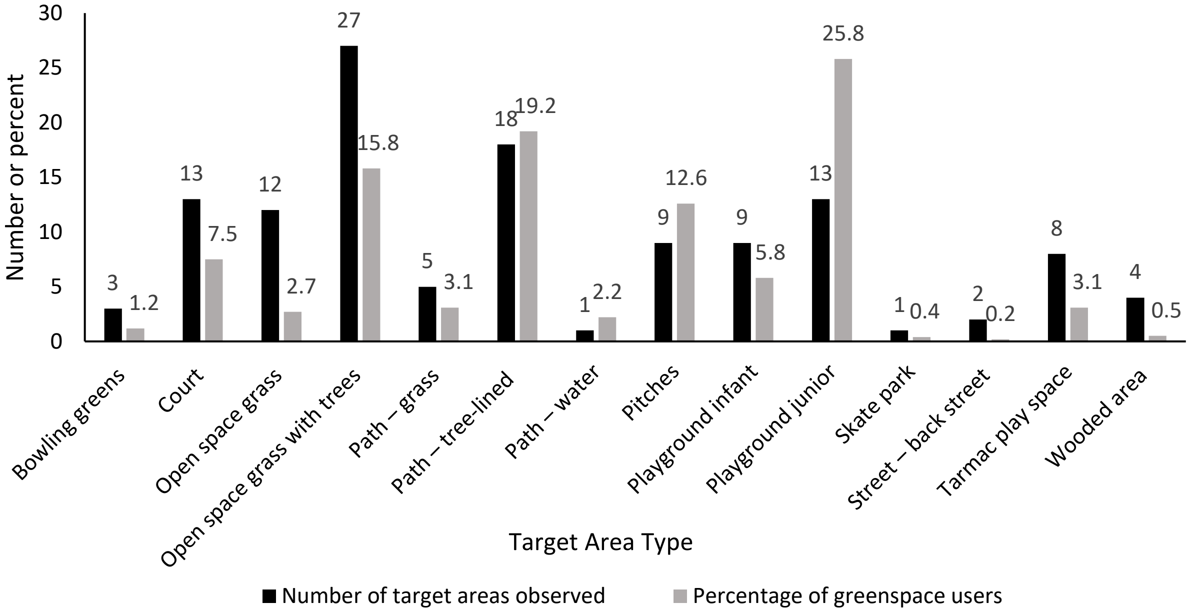


Figure 4.2). Infant playgrounds designed for younger children only accounted for 5.8% (n = 4020) of observations, despite having a similar number of scans (infant: 108; junior: 138 scans)(

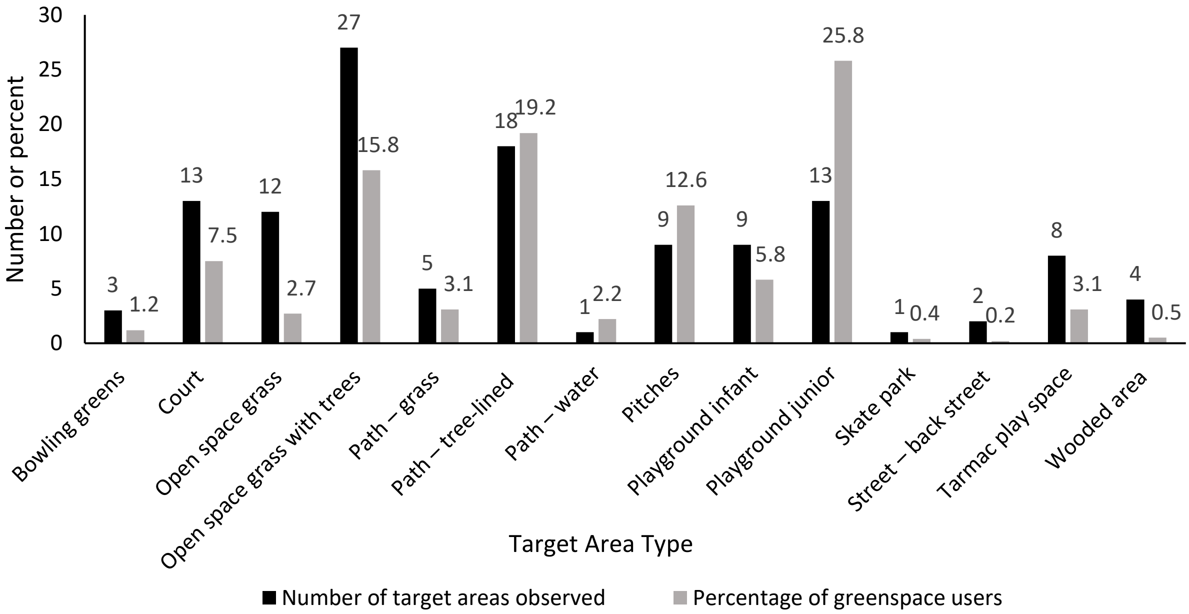


Figure 4.2). More adult females were observed in junior playgrounds compared to males (56.5 vs 43.5%, n=1036) (Table 4.8). Playgrounds attracted similar numbers of male and female children (0-12)(infant: 8-16%, n = 133; junior:42-46%, n= 573). Note that the majority of 0-4s were seen in the junior playgrounds compared to infant playgrounds (46.8% vs 13.5% of 0-4 observations, n = 406)(Figure 4.3). More males were observed using courts and pitches compared to females (courts: 67.33 vs 32.67%, n= 300; pitches: 52.47 vs 47.53%, n = 507).

Courts were used more by 12-16s compared to other age groups (17.6 vs 5.9 - 6.9%, n = 4020). A greater percentage of adults and those aged 12-16 used pitches compared to 0-11-year-olds (12-16: 15.5%, adults: 16.2% vs 0-4: 5.9%, 5-11: 5.0%, n = 4020) (Figure 4.3). There was low use of skate parks and tarmac play spaces (0-1.1 and 1.2-5.2%, n = 4020)(

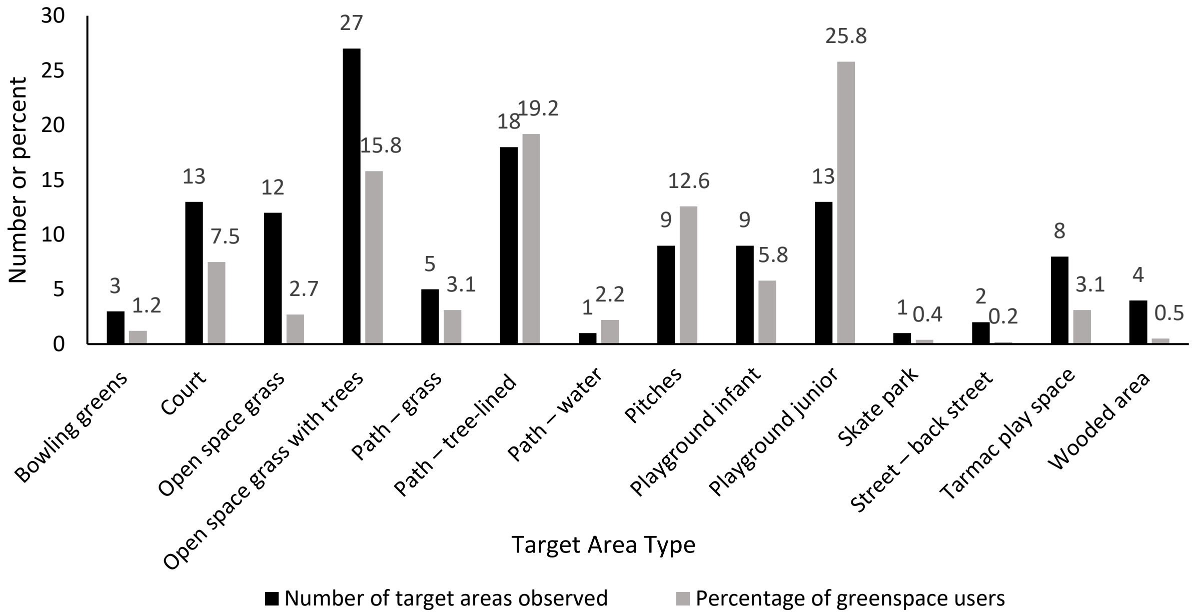


Figure 4.2).

Natural features

After playgrounds, features with trees such as open space with grass, and trees or tree-lined paths were the next popular features (15.8 and 19.2%, n = 4020). Features with trees had high use across all ages (tree-lined path: 9.6 - 25.3%; open space grass and trees: 9.9 – 17.7%, n = 4020). Despite the popularity of tree features, wooded areas were used by less than 0.5% (n = 4020) of park users and only by adults (0.8% of adult observations, n= 2277). There were significantly fewer people observed in wooded areas compared to all other features except backstreets which also had low use (p <0.0 01). Open space with trees had significantly more people observed compared to courts (p <0.001). There was also low use of open space that was grass only (without trees) across all ages (0.5 - 3.5%, n= 4020). More males were observed using tree-lined paths, water-lined paths, open space grass and grass with trees and woodland compared to females (Table 4.8).

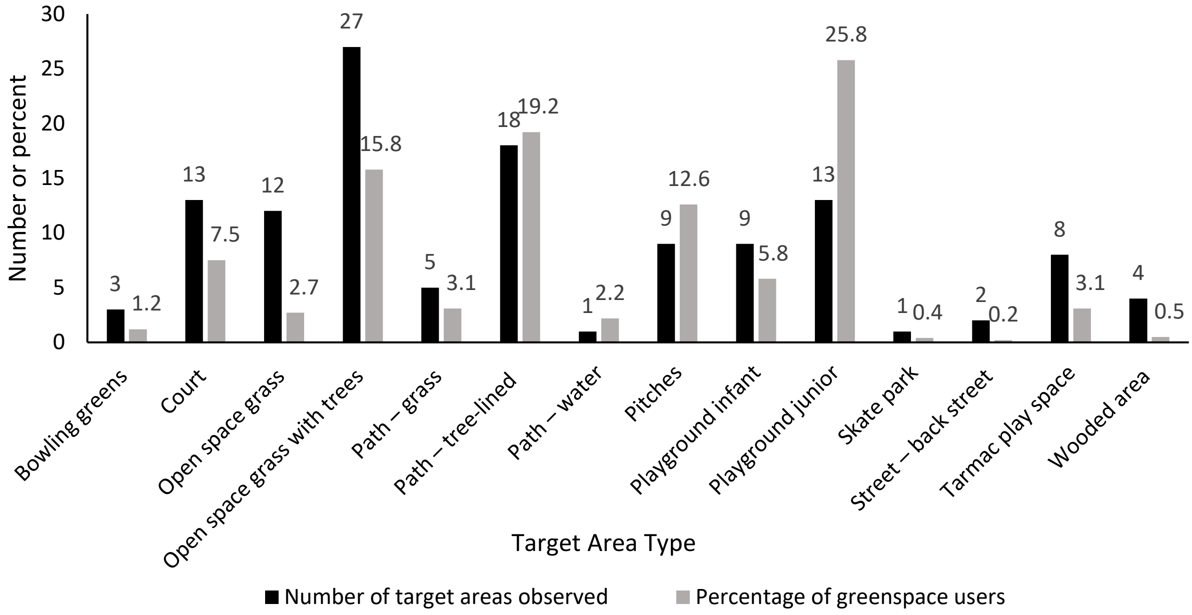


Figure 4.2. The percentage of observed park users (n= 4020) in each park feature type (n= 125 target areas observed).

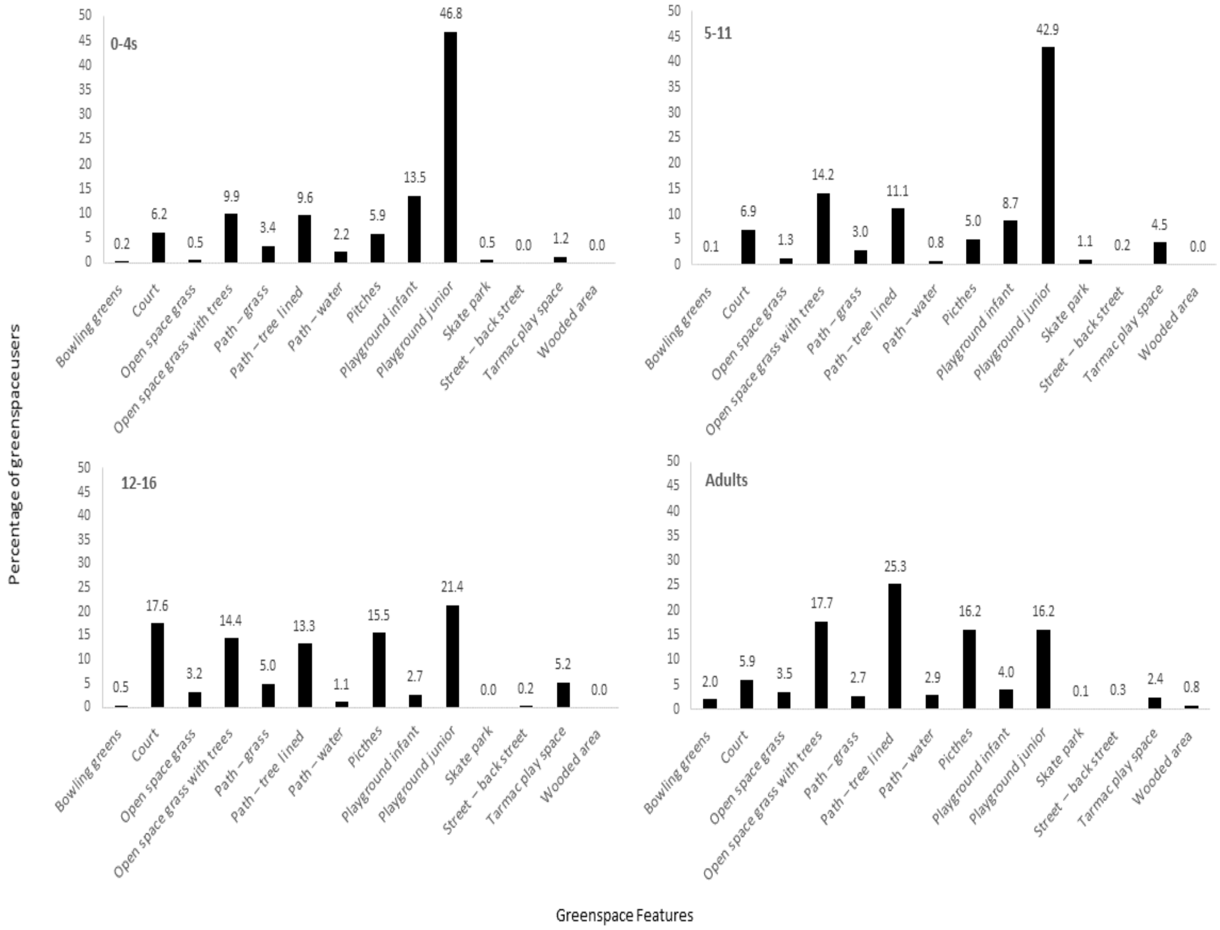


Figure 4.3. The percentage of observed park users in each park feature type in each age category 0-4 (n= 406.0), 5-11 (n= 893.0), 12-16 (n= 444.0) and over 16 years old) (n= 2277.0), (total n= 4020).

Table 4.8. Summary of activity levels for each feature by age group and gender (n=4020).

	0-4s															
					Sedentary				**Walking**				**Vigorous**			
	Total				**F**		**M**		**F**		**M**		**F**		**M**	
	count	**%**	**F**	**M**	**count**	%	**count**	%	**count**	%	**count**	%	**count**	%	**count**	%
Bowling greens	1	0	1	0	1	100	0	0	0	0	0	0	0	0	0	0
Court	25	6	12	13	1	8	3	23	10	83	9	69	1	8	1	8
Open space grass	2	0	2	0	2	100	0	0	0	0	0	0	0	0	0	0
Open space grass with trees	40	10	15	25	6	40	5	20	5	33	14	56	4	27	6	24
Path – grass	14	3	8	6	6	75	2	33	2	25	4	67	0	0	0	0
Path – tree-lined	39	10	21	18	12	57	8	44	7	33	6	33	2	10	4	22
Path – water	9	2	6	3	4	67	0	0	2	33	3	100	0	0	0	0
Pitches	24	6	17	7	6	35	2	29	7	41	5	71	4	24	0	0
Playground infant	55	14	27	28	9	33	14	50	16	59	10	36	2	7	4	14
Playground junior	190	47	100	90	34	34	28	31	58	58	51	57	8	8	11	12
Skate park	2	0	1	1	1	100	0	0	0	0	1	100	0	0	0	0
Street – back street	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tarmac play space	5	1	2	3	1	50	2	67	1	50	1	33	0	0	0	0
Wooded area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grand Total	**406**	**100**	**212**	**194**	**83**	**70**	**64**	**297**	**108**	**417**	**104**	**622**	**21**	**83**	**26**	**80**

	5-11s															
					Sedentary				**Walking**				**Vigorous**			
	Total				**F**		**M**		**F**		**M**		**F**		**M**	
	count	**%**	**F**	**M**	**count**	%	**count**	%	**count**	%	**count**	%	**count**	%	**count**	%
Bowling greens	1	0	1	0	0	0	0	0	1	100	0	0	0	0	0	0
Court	62	7	18	44	2	11	3	7	14	78	30	68	2	11	11	25
Open space grass	12	1	3	9	0	0	0	0	2	67	4	44	1	33	5	56

Open space grass with trees	127	14	50	77	5	10	6	8	38	76	50	65	7	14	21	27
Path – grass	27	3	11	16	0	0	1	6	10	91	13	81	1	9	2	13
Path – tree-lined	99	11	43	56	4	9	4	7	27	63	42	75	12	28	10	18
Path – water	7	1	0	7	0	0	0	0	0	0	7	100	0	0	0	0
Pitches	45	5	18	27	0	0	1	4	13	72	18	67	5	28	8	30
Playground infant	78	9	46	32	4	9	5	16	29	63	17	53	13	28	10	31
Playground junior	383	43	199	184	40	20	15	8	109	55	111	60	50	25	58	32
Skate park	10	1	6	4	2	33	0	0	0	0	0	0	4	67	4	100
Street – back street	2	0	1	1	0	0	0	0	1	100	1	100	0	0	0	0
Tarmac play space	40	4	15	25	6	40	2	8	8	53	20	80	1	7	3	12
Wooded area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grand Total	**893**	**100**	**411**	**482**	**63**	**133**	**37**	**63**	**252**	**818**	**313**	**794**	**96**	**250**	**132**	**343**

	12-16s															
					Sedentary				**Walking**				**Vigorous**			
	Total				**F**		**M**		**F**		**M**		**F**		**M**	
	count	**%**	**F**	**M**	**count**	**%**	**count**	**%**	**count**	**%**	**count**	**%**	**count**	**%**	**count**	**%**
Bowling greens	2	0	0	2	0	0	0	0	0	0	2	100	0	0	0	0
Court	78	18	22	56	5	23	8	14	9	41	29	52	8	36	19	34
Open space grass	14	3	8	6	2	25	0	0	3	38	3	50	3	38	3	50
Open space grass with trees	64	14	15	49	4	27	17	35	9	60	28	57	2	13	4	8
Path – grass	22	5	11	11	4	36	6	55	7	64	5	45	0	0	0	0
Path – tree-lined	59	13	26	33	9	35	15	45	16	62	18	55	1	4	0	0
Path – water	5	1	1	4	0	0	1	25	1	100	2	50	0	0	1	25
Pitches	69	16	1	68	0	0	8	12	0	0	40	59	1	100	20	29
Playground infant	12	3	5	7	3	60	0	0	2	40	3	43	0	0	4	57
Playground junior	95	21	42	53	16	38	10	19	9	21	31	58	17	40	12	23

Skate park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Street – back street	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Tarmac play space	23	5	10	13	8	80	9	69	2	20	3	23	0	0	1	8
Wooded area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grand Total	**444**	**100**	**141**	**303**	**51**	**323**	**74**	**274**	**58**	**445**	**165**	**592**	**32**	**232**	**64**	**234**

	Adults															
					Sedentary				**Walking**				**Vigorous**			
	Total				**F**		**M**		**F**		**M**		**F**		**M**	
	count	**%**	**F**	**M**	**count**	%	**count**	%	**count**	%	**count**	%	**count**	%	**count**	%
Bowling greens	46	2	7	39	5	71	15	38	2	29	21	54	0	0	3	8
Court	135	6	46	89	15	33	22	25	29	63	39	44	2	4	28	31
Open space grass	80	4	22	58	1	5	29	50	21	95	29	50	0	0	0	0
Open space grass with trees	403	18	197	206	38	19	62	30	151	77	133	65	8	4	11	5
Path – grass	61	3	32	29	7	22	12	41	25	78	16	55	0	0	1	3
Path – tree-lined	576	25	265	311	45	17	70	23	206	78	222	71	14	5	19	6
Path – water	66	3	28	38	6	21	4	11	13	46	33	87	9	32	1	3
Pitches	369	16	205	164	17	8	25	15	179	87	123	75	9	4	16	10
Playground infant	90	4	57	33	22	39	8	24	32	56	22	67	3	5	3	9
Playground junior	368	16	244	124	112	46	49	40	126	52	68	55	6	2	7	6
Skate park	3	0	1	2	0	0	0	0	1	100	2	100	0	0	0	0
Street – back street	6	0	0	6	0	0	0	0	0	0	6	100	0	0	0	0
Tarmac play space	55	2	36	19	15	42	4	21	21	58	14	74	0	0	1	5
Wooded area	19	1	4	15	0	0	7	47	4	100	8	53	0	0	0	0
Grand Total	**2277**	**100**	**1144**	**1133**	**283**	**323**	**307**	**364**	**810**	**919**	**736**	**949**	**51**	**58**	**90**	**86**

3. *Is the level of physical activity different in natural 'green' and non-natural 'grey' features?*

Non-natural features

Playgrounds: The most common activity in playgrounds was walking (infant: 55.7%, n = 235; junior: 54.3%, n=1036)(Figure 4.4). There were more sedentary park users in playgrounds than vigorous (infant: 27.7 vs 16.6%, n = 235; junior: 29.3 vs 16.3%, n=1036)(Figure 4.4). Children from 0-11 had similar activity levels in playgrounds (Figure 4.5). A higher percentage of 0-4 users were sedentary compared to vigorous in playgrounds (33-45 vs 10-11%, n = 55 vs 190) (Figure 4.5). When looking at the main activity of 0-4s the most common activity recorded for them was sitting in the pushchair (9 of 22 observations, note the small sample size) (Table 4.9). More 5-11s were vigorous than sedentary in playgrounds (28-29% vs 12-14%, n= 4610). Playgrounds also have the second-highest percentages of vigorous 12-16s observations (31-33%, n = 107) and more vigorous females compared to males (12-16: 40. 5% vs 22.6%, n= 42 vs 53) (Table 4.8). In playgrounds, a greater percentage of male adults were vigorous compared to female adults (5.6 % vs 2.4%, n= 124 vs 244) (Table 4.8). **Other non-natural features:** Walking was the most common activity in courts and pitches and there were similar levels of sedentary and vigorous activity (see Figure 4.4). Males often had a greater percentage of vigorous activity on pitches compared to females, except for 0-4-year-olds where more females were observed and with a greater percentage of vigorous activity compared to males (23.0% vs 0%, n = 17 vs 7)(Table 4.8). Courts were the feature with the highest percentage of active adults observed (22%, n=135). Across age groups, courts often had more male users however there were similar levels of activity in children (5-16). Skate parks were the only feature to have a greater number of vigorous users compared to walking (53.3 vs 26.7%, n= 15). However, there was low use of skate parks across the total sample (0.4% of n= 4020).

Natural features

The majority of users in natural features were walking (57.4 – 70.1%, n = 1726), then sedentary (17.2 – 31.5%, n = 1726) and then vigorous (3.2 – 12.6, n = 1726)(Figure 4.4). Only adults were observed using wooded areas of the parks (sedentary: 36.8%, walking: 63.12%, vigorous: 0%, n= 19)(Figure 4.5). Open space grass had high percentages of vigorous 5-16- year- olds (43-50%)(Figure 4.5). Open space with trees had a higher percentage of moderate to vigorous male children (0-11) compared to females and higher use by older male children (12-16) (49.00 vs 15.00, n =64) (Table 4.8). However, in open space with trees, similar numbers of 0-4 male and females were observed (25 vs 15) and higher percentages of children were vigorous compared to those in playgrounds (25 vs 10-11%, n= 40 vs 245) (Table 4.8). Paths had similar activity levels across ages and gender but there were occasions when females had a higher percentage of moderate or vigorous observations, these were on water-lined paths (adults) and tree-lined path (5-11 and 12-16) (Table 4.8).

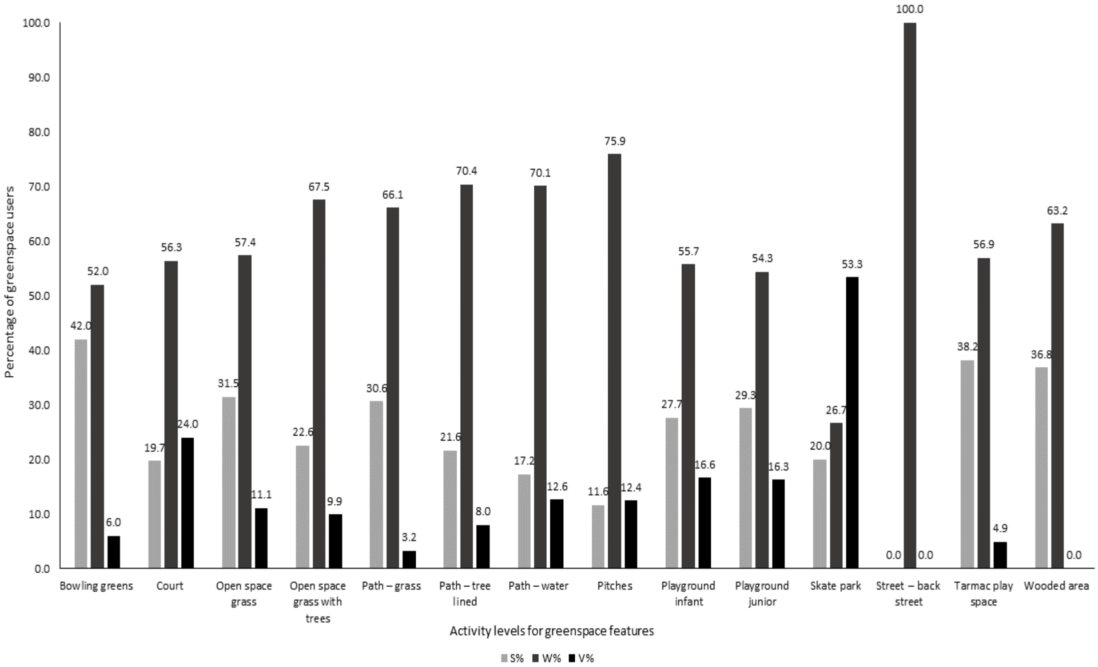


Figure 4.4. Park user activity levels across park features (s: sedentary, n=962.0, W: walking, n=2546.0, V: vigorous, n= 512.0)(n= 4020).

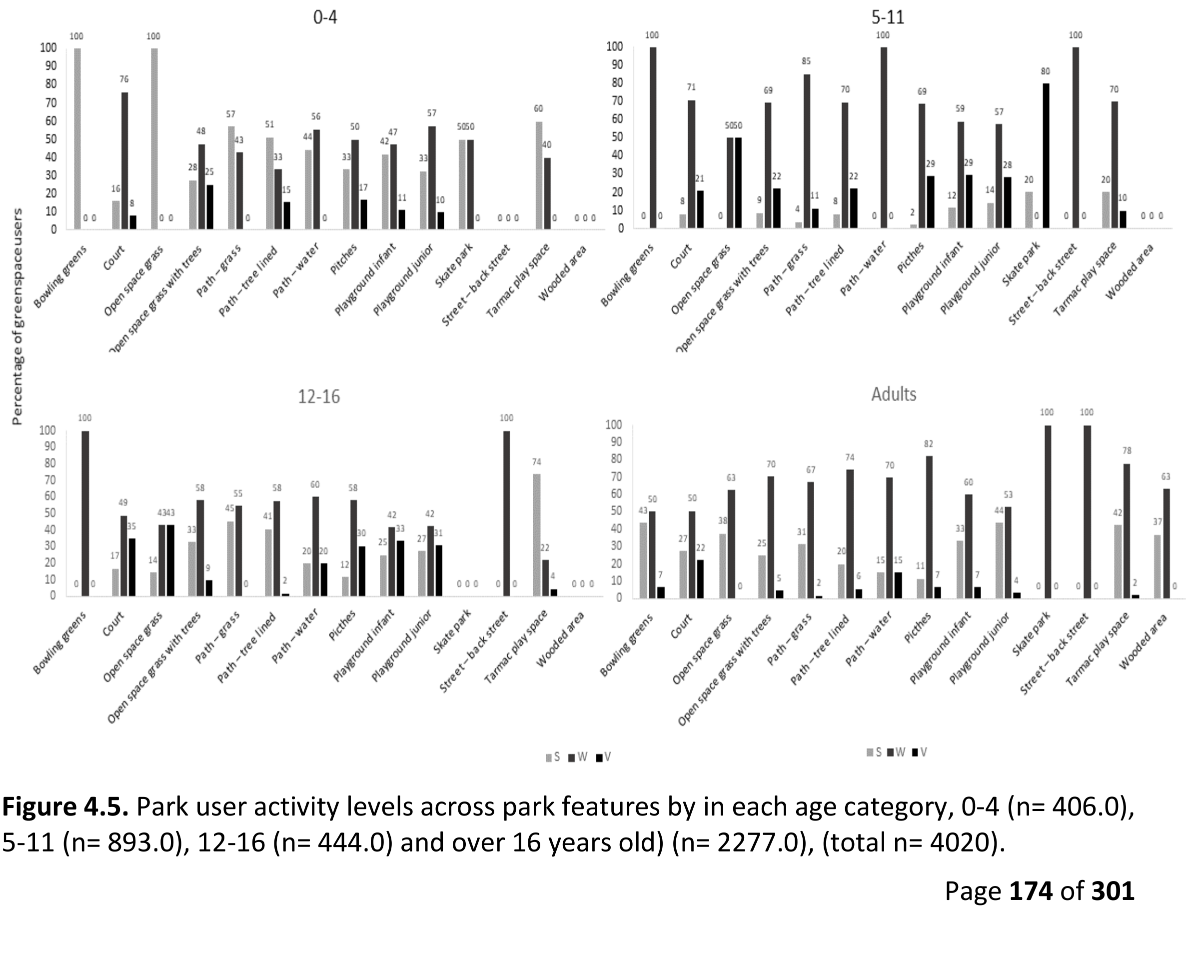


Figure 4.5. Park user activity levels across park features by in each age category, 0-4 (n= 406.0), 5-11 (n= 893.0), 12-16 (n= 444.0) and over 16 years old) (n= 2277.0), (total n= 4020).

Table 4.9. A Summary of the activities observed in each feature for those under 4 years old (n= 22 of 406 under 4s observed out of 4020 total observations).

Activity	Count	Female 0-4s (n= 12 observations)	Male 0-4s (n= 10 observations)
Push chair (9)	9	Path grass Playground junior Path tree Path water	Path grass Playground junior Courts
Swing (6)	6	Playground infant Playground junior	Playground infant Playground junior
Carried (2)	2	Open space – grass and trees Path grass	x
Climb (2)	2	Playground infant Playground junior	x
Slide (1)	1	Open space – grass and trees	x
Walking (1)	1	x	Open space – grass and trees
Running (1)	1	x	Path – tree-lined

4. *What are the barriers and enablers for use of natural 'green' and non-natural 'grey' features?*

To explore the observed patterns of use in more detail I used participant-led walks. The SOPARC tool only captures a snapshot of current use. On the walks participants can share ideas about barriers that could be removed and enablers that could be implemented to promote increased use of particular features. Here I compare results from both methods of capturing park use. The walks offer a unique perspective from carers or parents of young children (0-4 years old). If the greenspace is safe and accessible for this age group then it is likely to be safe and accessible for a broad spectrum of society. Quotes from participants are in italics.

Perceptions of patterns of use

Participants indicated high use of the parks in the afternoon or evening which aligns with the observation data that shows 62.9% (n=4020) of observations were in the afternoon or evening. Participants also identified school times as busy times in the parks and playgrounds. Other respondents described walking in the morning and the middle of the day.

Activities of park users

The most common activity mentioned by participants was play (30.9% of comments about activities), which is consistent with the observations where playgrounds had the most observations. Walking was the second most frequent activity mentioned (27.3% of comments about activities), which matched the observation data (63.3% walking observations, n = 4020). The participants also mentioned watching wildlife (10.9% of comments about activities), which was not captured by the observation method. Participants also mentioned other types of exercise (running, using exercise equipment and football, see Table 4.10).

Reoccurring themes across natural, built and social environments

Safety was a concern, especially when fewer people were present in parks (26.1% of comments about emotions). Other safety issues were associated with dense vegetation, certain buildings or fences, litter and sharps, anti-social behaviour and playground equipment (72.8% of comments about social environment and community)(Figure 4.6). Dogs and dog foul were cited as barriers to use of parks.

- *'I don't feel safe walking through this path anymore because I think it's overgrown and I can't see anything, the other time I walked over here I had to run because I was scared. It's so scary over here'*
- *'This makes me really sad. Dirty graffiti container…. It ruins the beautiful space and nice views.'*
- *'The park is very big and on sunny days it's very busy, very comfortable, very good to walk but on rainy days and cold weather there's nobody here and walking around makes me scared'.*
- *'My children love coming over but it's a bit dirty all the time that's why I don't have time to bring them here [to the water feature]'.*
- *'A few times they've had the incident with anti-social behaviour from young teenagers while they're running the [Forest School] session which has unfortunately meant a few times they have had to stop the session altogether and now they're thinking of doing the Forest School in their own grounds rather than using the park'*

Litter and sharps were a direct barrier to using particular features (paths, rocks, grass and water) and respondents said that the natural beauty of greenspaces was negatively impacted (64.0% of comments about social environment and community) (Figure 4.6). Concerns were also raised about disservices through encouraging rodents with litter or its negative impacts on desirable wildlife such as birds that use dirty water features (10.4% of comments on the natural environment).

- *'I think it's like dirty as if someone has burnt it because these small things spoil the beauty of the park'*
- *'There's loads of barbed wire and nails and broken fences, which makes it really unsafe for small kids. It's an ideal place to run about but unfortunately, it's unsafe',*
- *'Glass and rubbish make it impossible to walk without shoes. It doesn't make it safe for children to run around'.*
- *'In baby area, I sometimes see rats here which is very disgusting and dangerous for babies'.*
- *'I feel what's happening to the ducks and swans and what are they eating and what's going to happen to them. When I was very little this pond used to be so clean there was fishes in the pond but now they will die, I'm surprised the ducks haven't died''*

Playgrounds are enablers for greenspace use and are valued by the participants (19.0% of comments about the built environment) Participants identified a few barriers to using playgrounds (8.8% of comments on the social environment). For example, anti-social behaviour particularly vandalism or teenager presence can be a barrier to using playgrounds. Litter was also identified in playgrounds (6.1% of comments on the social environment). However, the use of playgrounds remained high, with some respondents raising the high use of playgrounds as a barrier to use, even changing the times they visit to avoid high use times. Although litter was seen in playgrounds, it is not mentioned as much as litter in other areas of the park where it may have a larger influence on decreasing use (Table 4.10). Participants also highlighted opportunities for further development of play equipment. Other built features that were enabling were wheelchair/pushchair-friendly entrances and paths. These became barriers when they were of poor quality or too small for pushchairs (particularly entrances designed to prevent quadbikes or motorbikes)(6.9% of comments about the built environment).

- *'Sometimes it gets really crowded and they just fight over it for swings and anything'.*
- *'The pavement is quite even. It's even good for running'*
- *'The uneven path, cracks, mean that kids can't ride their bikes and lots of tripping hazards'.*

Natural features were seen as a barrier to using greenspaces on the way to the park and in the park when vegetation is overgrown, messy, and comprised of spontaneous vegetation or plants perceived as dangerous (nettles or fallen trees)(see Figure 4.6). Natural features (particularly flowers, trees and birds) could also be an enabler and a motivation for using the greenspace for exercise, play, education and watching wildlife. Participants appreciated natural features but often the use was limited due to low quality (overgrown or messy) or accessibility (lack of paths) or litter. Participants spoke about how improved quality of these natural features would enable their use of them (water, grass, trees and rocks). Participants indicated valuing the spaces and features (particularly trees) by using positive language (such as “love”, “lovely”, “happy”, “nice”, and “lucky”) frequently (50.0% of comments about emotions).

- *‘I feel really lucky to have this space’*
- *‘I like the variety of trees and plants in Bradford moor park and also the space'*

Participants were asked to specifically highlight points of improvement. Other than requesting trimming vegetation participants did not request changes to the greenspaces that would decrease the natural elements, despite lower observed use in more natural areas compared to playgrounds. In fact, participants asked for additional natural features such as flowers or offered ideas to encourage wildlife.

- *‘The flowers are pretty. I like looking at them. I even take photos of them. We need more flowers’*
- *‘She loves watching the ducklings’*
- *‘They love coming here because of the tree because they can climb on that and hide over there. That area over there they play hide and seek over there because trees are like that and they have fun over there. It’s really nice and fun’.*
- *‘I love this view, I often walk this way to work as it makes me feel good at the start of the day. I think we are very lucky to have it.’*
- *‘It will be lovely if they have names on the tree so we can children about what tree it is because I don't even know myself what tree it is so I can’t even tell children what it is I just tell them it’s a tree’.*
- *‘Very large canopy trees, big open space, beneficial to community but could have a few more large canopy trees'*
- *‘Woodland, hear birds singing, densely vegetated, could be a nice play area for children’*
- *'Fallen tree is messy and unsafe for kids to play*

Table 4.10. Examples of comments for each of the themes raised by participants of the participant-led walks (n= 18 participants, 634 comments).

Themes	Topic	Example quotes:
Activities	Organised	'It's just really good', 'the fairground comes here when they come but they leave a big mess. It's just an empty space that's not being used and there's so much potential.'
Natural features	High quality	'This is such a lovely pond, the kids love it so much', 'lovely ponds with variety of birds, swans, geese, mallard ducks', 'the flowers are pretty. I like looking at them. I even take photos of them. We need more flowers'
	Open space	'I feel really lucky to have this space', 'it's good to have a gym that's free to use for anyone really and good to have it in an outdoor open space and the family can come along and exercise at the same time'.
	Low quality	'There is a lake here in this park and it is very dirty it's supposed to be clean and you know it's smelly and there are flies everywhere', 'very dirty and algae and smelly pond ', 'I feel what's happening to the duck and swans and what are they eating and what's going to happen to them. When I was very little this pond used to be so clean there was fishes in the pond but now they will die, I'm surprised the ducks haven't died', 'rubbish ruining what would be a nice area of grass' and 'rock feature ruined by rubbish and graffiti'.
	Vegetation	'I don't feel safe walking through this path anymore because I think it's overgrown and I can't see anything, the other time I walked over here I had to run because I was scared. It's so scary over here'. 'There is a dangerous holly bush here for children'.
	Trees	'I really like the trees we have around. We got some lovely large trees and they make me happy' and 'very large canopy trees, big open space, beneficial to community but could have a few more large canopy trees', 'woodland, hear birds singing, densely vegetated, could be a nice play area for children', 'fallen tree is messy and unsafe for kids to play'.
	Wildlife	'she loves watching the ducklings', 'they love coming here because of the tree because they can climb on that and hide over there. It's really nice and fun', 'It will be lovely if they have names on the tree so we can teach children about what tree it is it because I don't even know myself what tree it is so I can't even tell children what it is I just tell them it's a tree but which tree', 'because of this [litter] you get so many flies', 'in baby area, I sometimes see rats here which is very disgusting and dangerous for babies'.
Grey features	Playgrounds	'We love the park, we love that there a playground, where we can come and play here', 'lovely playground, lots to do', 'Evenings it is very busy here with babies and families', 'sometimes its proper dirty everywhere. I also think the swings some chains are bad and it's like dangerous', Sometimes it gets really crowded and they just fight over it for swings and anything'.

	Roads	'[We're] able to use safer and quiet back roads to park'
	Buildings	'It's [an old building] just dangerous. It needs to be pulled down or made secure. People sleep in it and stuff' 'this makes me really sad, dirty graffiti container. It ruins the beautiful space and nice views and it makes people feel unsafe.'
	Fences	'I don't like these types of fence because it makes me feel like I can't see on the other side and it makes me feel really scared' and 'wall with barbed wire. Makes me feel unsafe. There's a nice view behind it but you can't see it'
	Entrances	'very pushchair and wheelchair friendly and able to get into from all sides', 'this entrance is too small, wheelchairs or pushchairs can't fit through it', 'barriers are rusty'
	Path	'The pavement is quite even. It's even good for running', 'the uneven path, cracks, mean that kids can't ride their bikes and lots of tripping hazards'
Social	Litter	'It's just not nice having to look at all the rubbish that is just a small bit but as you're walking along there's rubbish everywhere and it just doesn't make you feel good', 'rubbish ruining what would be a nice area of grass' '[the water] so beautiful I love it so much but it's so dirty and people just throw stuff', 'litter in water dirty water - my children love coming over but it's a bit dirty all the time that's why I don't have time to bring them here', 'sometimes it's really dirty and you can't even sit there unless you clean it with a wipe or something'
	Sharps	'wine bottles are scattered everywhere over here. Sometimes when the kids pass by it's dangerous for them', 'there's often lots of bits of glass which makes it really unsafe for kids to run about and play about and let them run off by themselves', 'there's loads of barbed wire and nails and broken fences, which makes it really unsafe for small kids. It's an ideal place to run about but unfortunately, it's unsafe', 'would you like your child or your toddler to be playing near this nail?'
	Antisocial behaviour	'I think it's like dirty as if someone has burnt it because these small things spoil the beauty of the park', 'someone was driving and rammed it inside the fences and the car went on fire', 'wooden equipment has been vandalised and not repaired. So people don't use it'
	Community	'the park is very big and on sunny days it's very busy, very comfortable, very good to walk but on rainy days and cold weather there's nobody here and walking around makes me scared', 'it gets dark by 10 but in wintertime, not many people walk around 4 o'clock', 'sometimes it gets really crowded and they just fight over it for swings and anything'
	Dogs	'People they let their dogs free and it really really scares me and I don't like it', 'so there is a sign here which says no poo from any dogs but nobody noticed and they are doing it all the time [not picking up dog poo]', 'there's always dog poo on the sides'.

Figure 4.6. This collage displays participant pictures of barriers to use for a single greenspace as an example of data collected. a) vegetation overhanging the path b) nails and wood on a path connecting two greenspaces c) is a part of greenspace with trees that participants wanted to use d) showing fenced-off wooded area participants were interested in using e) unfriendly fencing along a path joining two greenspaces f) unsafe area joining two parts of greenspace g) unsafe broken wire fences in wood area participants expressed interest in using h) container for sports club equipment but identified as negative impact on the view (n= 18 participants).

4.5 Discussion

I found that park users had preferences for using playgrounds and features with trees (paths or open spaces). Although woods (arguably the most natural feature) was used by just a few adults but there was a desire to use this area. Use of the wooded area could increase if specific barriers such as overgrown vegetation are removed and more accessible paths to be installed. Participants also asked for certain natural features (such as flowers) to be increased in greenspaces. The links between these more natural features and physical activity are unclear, on a park level more sedentary activity was observed in parks with higher tree species richness. The results counter some prevailing common sense assumptions on greenspace use. For example, one assumption is that playgrounds encourage physical activity yet here I show that almost a third of observations were sedentary and for younger park users they are more active in other features such as open space with trees. This study also begins to unpack the variety of ways that people can benefit from using greenspaces, for example, this study shows that higher biodiversity was more likely to decrease observations of walking and increase sedentary behaviour, which could offer wellbeing benefits but these are different to the benefits achieved by higher levels of physical activity.

Weather and park quality (NEST score) influenced park use; there were more park users in better weather in parks of higher quality. While weather increased the number of observations in each activity level, the quality did not influence activity levels. Parks with good facilities and low incivilities have been associated with higher use and a higher likelihood of moderate and vigorous activity (Knobel et al., 2021). The size of the greenspace had no association with the number of observations or activity levels which is unexpected as larger parks can offer more facilities, space, natural features and biodiversity. One explanation is that the playgrounds are the most used feature in this study and even smaller greenspaces often had a playground, which promotes higher use. Previous research highlights the enabling effect of playgrounds finding that smaller parks (less than a half-acre) with playgrounds had a similar level of users to the playground areas in larger parks (Cohen et al., 2014).

The playground is the most visited feature of the greenspaces and had high use among children and adults in this sample, in line with previous literature (King et al., 2015; Chow et al., 2016). Playgrounds were described as enabling features by participants and they did not express the same barriers for playgrounds as the other parts of the greenspaces, it appeared that anti-social behaviour and litter occurred mainly outside of the playground. When these barriers were identified in playgrounds they did not prevent use. For example, litter in playgrounds was identified but some participants spoke about the same playground being too busy despite litter or unsafe equipment. This highlights the importance of playgrounds; greenspace users use them even with reduced quality.

Previous studies have found that playgrounds are usually used by children under 10 years old which complements the results from this study (Loukaitou-Sideris and Sideris, 2009; Baran et al., 2014). Although I saw sustained use across all age groups. Playgrounds can promote activity (Shores and West, 2008), particularly high levels of activity for children (Shores and West, 2008; McCormack et al., 2010; Reed and Hooker, 2012; Besenyi et al., 2013; Lindberg and Schipperijn, 2015; Jenkins et al., 2015; Marquet et al., 2019). Although I observed some vigorous activity levels in playgrounds, the majority of users in this study had medium activity levels. When scrutinising the physical activity of children aged 0-4, there were more sedentary than vigorous observations in playgrounds. This could be due to young children sitting in pushchairs while parents or carers observed older children. For example, more 0-4s were observed in junior playgrounds with equipment only suitable for older children. There were also more adults being sedentary compared to vigorous in playgrounds. Future playground designs could encourage play activities that require active movement of both children and adults simultaneously.

The disproportionate use of playgrounds compared to other features of the greenspace has implications for design and management. Arguments could be made to focus resources on expanding the number and size of playground areas, as well as managing barriers such as litter or broken equipment to support use. However, the participants spoke about wanting to use other features (trees, water and open space) and the potential for these features if barriers such as litter and safety concerns were reduced. Therefore, a dual approach could offer opportunities for increasing use, activity level, natural play, and nature connection. Organised activities that utilise the other spaces could increase the use of and activity levels in other features. For example, Forest School activities can promote physical development and build stamina through whole-body movements such as walking, traversing rugged terrain, collecting and moving materials and building or destroying structures (O'Brien and Murray, 2007). These benefits were most noticeable for those under 5 years (O'Brien and Murray, 2007).

Paths enabled greenspace use and walking, especially when they were pushchair and wheelchair friendly and maintained to a high quality. Tree-lined paths were used more than grass or water-lined paths. Previous studies have found that paths are a well-used park feature and sometimes with the highest levels of activity compared to other park features (Reed et al., 2008; Shores and West, 2010; Besenyi et al., 2013; Van Hecke et al., 2017). However, muddy paths were a barrier to use by the sample. Yet a previous study found that users of natural surface trails were active for longer and were more vigorous than those using paved trails (Reed et al., 2009). If natural surface trails could be introduced in an accessible way there is potential for higher activity and activity for longer. Another study found that adding patterns and markings to paths could increase activity (Igel et al., 2020).

Although biodiversity (species richness of birds, bees, butterflies and trees) did not have an association with the number of observed park users, higher tree species richness was associated with higher observations of sedentary activity. This may be linked to the restorative nature of biodiversity and park users seeking more diverse areas to sit and relax or to picnic (Kaplan and Kaplan, 1989; Wood et al., 2018; Knobel et al., 2021; Marselle et al., 2021). To the authors' knowledge, there has only been one other study carried out (with one planned) that explores links between activity and park use using SOPARC and biodiversity aspects (Pearson et al., 2020; Knobel et al., 2021). Knobel et al. (2021) found that bird biodiversity (as opposed to other animal biodiversity (note plant biodiversity was not measured) was positively associated with the use of greenspaces. They also found that bird biodiversity had a positive association with physical activity, which contrasts with my findings where there were no significant relationship with bird species richness. There were high incivilities present in the study, which may counter the positive effect of biodiversity providing motivation for exercise, for example, overgrown or thick vegetation tends to be a litter trap and avoided by park users.

A novel aspect of this study is that I explored the impact of biodiversity on a smaller scale, a SOPARC target level whereas previous studies explore this at the park level. Here only tree and plant species richness had significant relationships with the number of people observed (more tree species more people observed but more plant species fewer observations). Target areas with higher species richness, including plant species richness had fewer walking observations. Target areas with more plant species are likely to be scrub-type habitats, which can be perceived as messy or dominated by spontaneous vegetation. There are very few flowerbeds in the study sites which if they were present could potentially encourage the use of a target area and increase biodiversity (Southon et al., 2017). Bird species richness and abundance did not have a significant impact on the use or activity level of a target area, contrasting with (Knobel et al., 2021). The relationship between biodiversity and activity level remains unclear, as tree species richness had no significant relationship with activity level.

However, natural features with trees had high use and medium activity levels and were preferred over their treeless counterpart (paths or open space without trees). Park users identified trees as positive features providing opportunities for relaxing, watching wildlife and natural play. Previous research has found that the wellbeing benefits from visiting areas with trees lasted up to 7 hours (Bakolis et al., 2018). Another study found that spaces with grass and trees had higher use (for individuals and groups) compared to spaces without 'green' features (Sullivan et al., 2004). However, in this study, the wooded areas had very low use, with only adults (mostly male) using this area. Participants identified the wooded areas as having potential for use but expressed that areas of dense vegetation felt unsafe and untidy.

Woods, particularly close to urban areas can be perceived as unsafe (Schroeder and Anderson, 1984; Burgess, 1995; Jorgensen et al., 2002; Bell et al., 2003; Jorgensen and Anthopoulou, 2007; Milligan and Bingley, 2007; Jansson et al., 2013; Sreetheran and van den Bosch, 2014). For example, one study in Scotland found that in one school the police had informed pupils not to enter the nearby woods because it was unsafe (Bell et al., 2003). Parents in the same study also thought the woods to be unsafe for children and youth to go unsupervised, while some children said that they felt safe in the woods even if parents were concerned about their safety (Bell et al., 2003). I identified similar barriers to use (such as litter and anti-social behaviour, particularly among teenagers)(Burgess, 1995; Bell et al., 2003; Jorgensen and Anthopoulou, 2007). Yet, woods can offer the opportunity for natural play, exploration, thrill of adventure, relaxation, learning, social interaction, freedom, and connection to the past (Burgess, 1995; Bell et al., 2003; Jorgensen and Anthopoulou, 2007; O'Brien and Murray, 2007; Milligan and Bingley, 2007; Jansson et al., 2013; Brussoni et al., 2015; Coates and Pimlott-Wilson, 2019). Additionally, Thompson et al., (2008) found that adults that were more open to visiting woodlands or green spaces alone had frequent visits to a natural place during childhood. There are missed opportunities for these activities and experiences when urban woods and other greenspaces are not used (O'Brien and Murray, 2007; Brussoni et al., 2015; Coates and Pimlott-Wilson, 2019). Cutting back or managing dense vegetation could also help park users feel safer, particularly if they can see through the vegetation to the other side (Burgess, 1995; Jansson et al., 2013). Previous literature has found that park users prefer 'half open' parks compared to areas of complex vegetation and park users show a preference for a medium level of human influence on natural features (trees, water, vegetation and planting) and dislike uniformity, artificial modifications and very mature vegetation (Nordh et al., 2009; Nordh and Østby, 2013; Qiu et al., 2013; Rupprecht and Byrne, 2014). Organised walks, providing maps, having seating and ranger patrols may also increase the use of wooded areas (Jorgensen and Anthopoulou, 2007).

Open space was appreciated by park users for the space itself, views, and play opportunities. However, open space without trees had relatively low use, and for some ages, low activity levels (for example, no 0-4s or adults were observed to be vigorous) but 5-16-year-olds showed similar levels of vigorous and walking activity in open space. Trees in open space can enable higher activity levels, for example, a higher percentage of vigorous 0-4-year-olds were observed in open space with trees compared to playgrounds. Previous literature has found that open space is used frequently by children and is important for moderate activity levels in both adults and children (Floyd et al., 2011; Besenyi et al., 2013). Open space can also encourage similar numbers of boys and girls unlike other features such as courts or pitches (Floyd et al., 2011; Reed and Hooker, 2012). Increasing play opportunities in open space could help younger children (0-11 years) be more active when they visit a greenspace and help promote equal use across sexes. While structural changes in playing fields can increase park use for both sexes, programming activities can significantly increase park use by teenage girls (Tester and Baker, 2009; Cole et al., 2023). Therefore, having organised or supervised activities in open spaces could potentially increase the use of these areas and higher activity levels (Floyd et al., 2011; Baran et al., 2014; Hillier et al., 2016). The concentrated use of playgrounds can lead to disservices such as conflict over limited equipment or lower activity levels for younger siblings and parents as they observe those using playgrounds. However, physical activity could be encouraged by increasing (and maintaining) the quality of other park features such as paths, open space, and woodlands. These features were identified by participants as having potential and they indicated a willingness to use these features if they were maintained at a high quality.

4.6 Conclusion

This study demonstrates that mixed-methods approaches are important for understanding greenspace use. Observations will only capture current use and not aspirational use or motivations behind patterns of use. If the SOPARC observations were used independently then it would suggest that natural features are not used despite availability. Once the qualitative data is integrated, park users are interested in using these spaces and they value particular features such as trees and low use is associated with poor quality of the natural features or feeling unsafe. Observational data found that the type of feature had a significant influence on park use. For example, playgrounds are important as they can promote use across ages and genders with the potential for high activity levels. However, disproportionate use of playgrounds means that park users (particularly children) are missing opportunities for nature connection, natural play and experiential learning. Park users valued natural features (particularly trees) and expressed interest in using natural features (including for natural play) but concerns about quality and safety were barriers to use. Improving the quality of the natural features through cutting back vegetation, removing litter, and increasing safety would promote use. Programming activities or events in natural greenspace features could encourage use and physical activity. The relationship between biodiversity and promoting either physical activity or restorative benefits needs to be explored further. Although biodiversity had no significant impact on the number of users in an area, there was a mixed relationship with activity level. For example, trees were an important feature for motivating use, however, larger stands of trees were perceived to be unsafe and had low use. Bird biodiversity and abundance had no significant relationship with use or activity level. However, park users valued birds (such as ducks) and suggested that increasing natural features (including biodiversity) would improve greenspaces. To maximise the physical, emotional and mental benefits of urban greenspaces the use of natural features should be facilitated alongside the use of non-natural features such as playgrounds.

5 A walk in the park: Identifying win-win greenspace features that are attractive, safe and promote benefits for nature connection, wellbeing and biodiversity

5.1 Abstract

Urban greenspaces can support good health, wellbeing, and biodiversity. However, previous literature and evidence from this thesis has shown that there are trade-offs in urban greenspaces where features that support high biodiversity can be perceived as messy, unattractive and unsafe. These negative perceptions can influence how the greenspace is used and the associated benefits for wellbeing or nature connection. Therefore, I take a multidimensional approach to capture the trade-offs between biodiversity, safety, attractiveness, nature connection and wellbeing in relation to different greenspace features. Greenspace features included cafés, concrete sports areas (hereafter 'courts') court, entrance, formal planting, grass, grass (hill), playgrounds, pitches, scrub, tarmac, tree avenue, water, wood and wood edge. A total of 75 people participated in guided walks through one of four greenspaces, visited a specific set of waypoints, and were asked to score particular features for biodiversity, safety, attractiveness, nature connection and wellbeing. Participants could also take photos of the features. Data from these walks showed that only courts were scored as unsafe and that grass hills were scored as most safe. Formal planting, grass (hill), pitch and wood edge scored high for attractiveness. Courts and entrances scored low for wellbeing and wood edge scored highest for wellbeing. No features scored low for nature connection and many features scored highly, while only the wood edge was scored as being wild. When asked which features they would visit again, courts scored low and only formal planting scored high. Win-win features that scored well across the dimensions of attractiveness, safety, biodiversity and wellbeing included formal planting, grass, pitch, scrub, wood and wood edge. I suggest that greater coverage of these features can facilitate park use and nature connection opportunities. As the walk itself may influence participants' perceptions of the greenspace, I collected data on greenspace satisfaction, wellbeing, nature connection and perceived biodiversity before and after the walk. Wellbeing was significantly higher after the walk but there was no significant difference in satisfaction, nature connection or perceived biodiversity. However, qualitative responses from the participants showed that participants enjoyed the walks, found new areas of greenspaces (even though they had visited before) and would use the greenspace differently (such as noticing or learning about wildlife on future visits). I show that it is possible to support biodiversity without challenging safety and provide attractive

features that provide opportunities for wellbeing and nature connection. Addressing the trade-offs and identifying features with public consensus and benefits for biodiversity is key for decision-makers in times of limited resources for greenspace management.

5.2 Introduction

Increased urbanisation can negatively influence biodiversity and human health and wellbeing. Therefore, it is important to create refuges for wildlife and mitigate negative impacts for human health and wellbeing within urban environments. Urban greenspaces have been shown to support biodiversity and positive health and wellbeing outcomes (Frith and Gedge, 2000; Helden and Leather, 2004; Saarinen et al., 2005; McKinney, 2006; McKinney, 2006; Fuller et al., 2009; Hale et al., 2012; Lovell et al., 2014; Nielsen et al., 2014; Lee et al., 2015; World Health Organization, 2016; Hayhow et al., 2016; O'Sullivan et al., 2017; Samuelson et al., 2018; Cox et al., 2018; Hayhow et al., 2019; Kettel et al., 2019; Cronin-de-Chavez et al., 2019; Marselle et al., 2021). However, the benefits depend on the greenspace design (Beninde et al., 2015). It is clear from literature and the findings in Chapter 4 of this thesis that there are trade-offs experienced in urban greenspaces, between biodiversity and safety or attractiveness. Indeed, natural areas can be seen as untidy or neglected. The untidy appearance was highlighted as a signal that may encourage anti-social behaviour. This is supported by the broken windows theory, that small scale crime such as broken windows or vandalism that goes unaddressed acts as a signal to others and increases the concentration of anti-social behaviour in a space perceived to have little monitoring or use (Wilson and Kelling, 1982). Greenspaces can also generate negative outcomes and perceptions such as aesthetic (e.g. untidy vegetation) or health and safety concerns (e.g. allergies, unsafe water features, wild animals) (Lyytimäki et al., 2008; Escobedo et al., 2011; Birch et al., 2020; Marselle et al., 2021).

Therefore, it is important to understand how greenspaces could support people and biodiversity through safe and attractive features. Understanding people's preferences for features and why certain features are used while others are not can help identify win-win features for biodiversity and people. Exploring how biodiversity can enable (or limit) the use of greenspace can inform management decisions to maximise these benefits. As greenspaces are often managed for the public with public money it is key to have broad public acceptance of these features, which can be challenging as people can have varying perspectives and uses of urban greenspaces (Ode Sang et al., 2016). Specific features of biodiversity can also influence perceptions of urban greenspaces such as perceived naturalness, attractiveness, colour, species richness or evenness and structure (Schroeder, 1982; Schroeder and Anderson, 1984; Hands and Brown, 2002; Bjerke et al., 2006; Van den Berg and Koole, 2006; Nordh et al., 2009;

Lindemann-Matthies et al., 2010; Nordh and Østby, 2013; Weber et al., 2014; McMahan et al., 2016; Hoyle et al., 2017; Harris et al., 2018; de Bell et al., 2018; Hoyle et al., 2019; Wang et al., 2019; Mouratidis, 2019)

To explore these perceptions, mixed-methods are necessary. Chapter 3 demonstrates that traditional methods of measuring green exposure neglect biodiversity (particularly in top-down spatial analysis). It has been shown that biodiversity can have positive impacts on health but these studies don't usually capture perceptions of features in relation to biodiversity or other important dimensions of greenspaces perceptions (Hunter and Luck, 2015). In Chapter 3, I demonstrate that species richness has a relationship with wellbeing outcomes and that the relationship is complex as individuals were more likely to have more severe depression with greenspaces with higher species richness. However, in Chapter 4, I show that when using qualitative data, participants wanted more biodiversity and to use the natural features more but there were trade-offs for their safety and attractiveness when it came to using more natural features (such as woods). I also observed that (in Chapter 4) greenspace users use particular features of a greenspace more than they use others. For example, the most biodiverse areas within and at the edges of woods aren't used, yet participants highlighted wanting to use these spaces more. It was apparent that there were sometimes trade-offs between biodiversity, safety, wellbeing and attractiveness.

To capture user perceptions and wellbeing concerning a range of features as they moved through the greenspaces, I used a guided walk methodology allowing participants to take notes and pictures at a set of waypoints through a greenspace. Participants were asked to score the waypoints for biodiversity, attractiveness, safety and wellbeing. I also asked participants how connected to nature they felt at each waypoint because nature connection can influence the wellbeing benefits from the environment (Dobson et al., 2021; Richardson et al., 2021; Pocock et al., 2023). Richardson et al. (2021) argue that nature connectedness is a psychological requirement for positive wellbeing. Therefore, nature dose and nature connectedness should be explored simultaneously in urban greenspace studies investigating health and wellbeing outcomes. Biodiversity within greenspace plays a role in promoting health and wellbeing (Fuller et al., 2007; Dallimer et al., 2012; Lovell et al., 2014; Hoyle et al., 2017; Cox et al., 2018; Public Health England, 2020; Cameron et al., 2020; Dobson et al., 2021; Methorst et al., 2021; Marselle et al., 2021). In particular, birds, trees and flowers have been linked to greenspace users reporting higher wellbeing (Dallimer et al., 2012; Wheeler et al., 2015; Hoyle et al., 2017; Wood et al., 2018; Wyles et al., 2019; Cameron et al., 2020; Methorst et al., 2021). Even just perceived biodiversity can promote higher wellbeing (Fuller et al., 2007; Dallimer et al., 2012; Ode Sang et al., 2016; Southon et al., 2018).

I recognise that the method of a cognisant walk through the greenspace that asks participants to notice and comment on their perceptions of greenspace features and biodiversity may influence the participant's wellbeing and perceptions of the greenspace. For example, studies that prompted participants to notice nature over short periods (5-7 days) saw improved wellbeing compare to controls (Richardson and Sheffield, 2017; Bakolis et al., 2018; Dobson et al., 2021; McEwan et al., 2021). Visits as short as 15 minutes have been shown to have positive impacts on wellbeing and the sum of frequent short visits can offer similar benefits compared to longer visits (Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Roberts et al., 2019; Dobson et al., 2021). These benefits can be independent of an individual's surrounding residential environment if they choose to visit an urban greenspace these individuals can have similar benefits to those that live in a different residential environment (Cox et al., 2018). Therefore, I recorded the participant's wellbeing, perceived biodiversity, satisfaction and nature connectedness before and after the walk.

In this chapter, I explore the following research questions:

- How do people perceive different greenspace features with reference to the following dimensions of experience: attractiveness, safety, wellbeing, nature connection and biodiversity?
- Are there features that score high across all the dimensions and offer win-win opportunities?
- How does actively thinking about greenspace features while walking through a greenspace influence perceptions of that greenspace?

5.3 Methods

Study setting

This study took place in the city of Bradford in Northern England in the United Kingdom. Bradford has a population of approximately 500,000 people (2021 census, Bradford Metropolitan District Council, 2022a). This study takes place in three adjacent multi-ethnic electoral areas, which are some of the most diverse in Bradford (Kelly, 2015). These wards are also some of the most deprived when compared to UK average on the index of multiple deprivation (IMD, 2019). This study took place as part of the wider work on the Better Start

Bradford Better Place Project, which aims to improve health outcomes for children under four years old (Better Start Bradford, 2023).

This study uses the 'Greenspace Scotland' definition of greenspaces: 'any vegetated land or water within an urban area' (Greenspace Scotland, 2021). The study area has a variety of greenspaces, with a few large parks (over 10 hectares) and many pocket parks and informal greenspaces. This study took place in five parks spread across the three wards (Figure 5.1). These greenspaces were selected due to being a similar size but each had a different mix of features (offering common and unique waypoints) and level of biodiversity. I selected a greenspace from each area of the study area to capture the perceptions of communities across the study area.

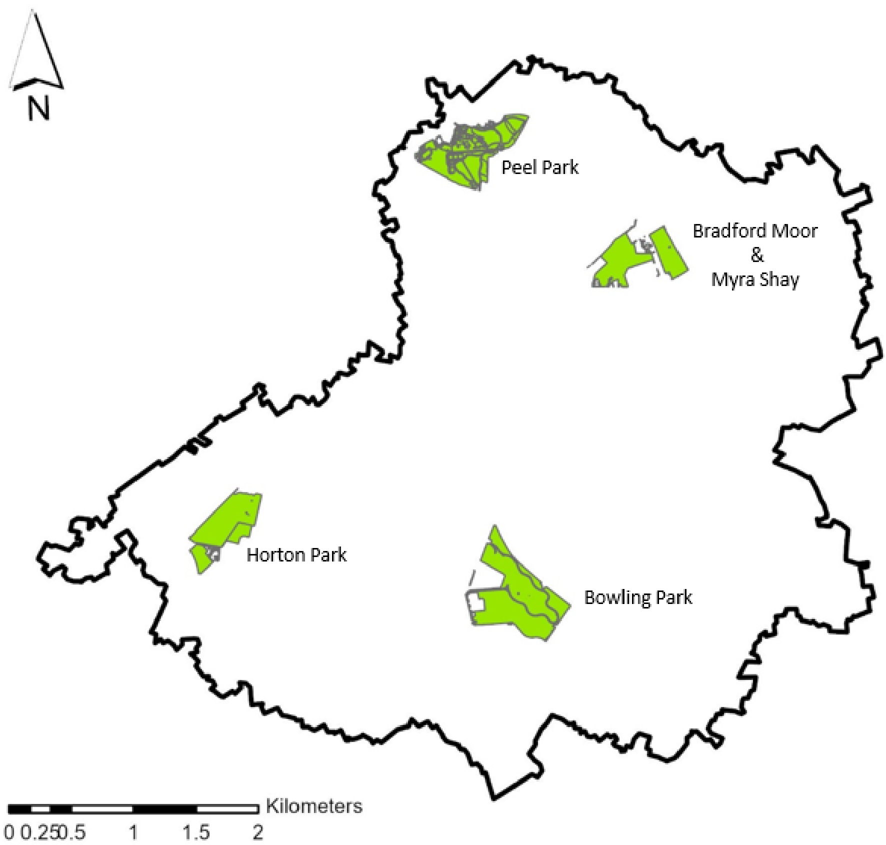


Figure 5.1. Shows the five greenspaces used in the guided walks for this study and their distribution across the study area. Contains OS data © Crown Copyright OS Open Green Space (2023).

Data collection

Greenspace quality including biodiversity

To understand what influences greenspace use I collected data on biodiversity of the greenspaces. The Natural Environment Scoring Tool (NEST)(Gidlow et al., 2018) was used to assess the presence/absence of features and condition of the environment in order to evaluate the overall quality of the parks and other green spaces. A higher score indicates higher quality of amenities. The tool involves summing scores for each greenspace across eight categories: access, recreation facilities, amenities, aesthetics (natural and non-natural), incivilities, safety and usability. As the scoring is subjective, at least two researchers scored the park in each category to allow for an average score for each park to be calculated. Data collection took place in 2018 and 2019; there was no significant difference between the years, therefore scores were averaged for each greenspace.

To record birds, bees, butterflies and trees transects that crossed each type of habitat in the greenspace were used (recording things 2.5 m either side) (Pollard et al., 1986; Fuller et al., 2007). Transects were carried out at times that would represent park user experience of biodiversity (8.30 am – 5 pm). Transects were also conducted when there were appropriate conditions (sunny days above 13℃ or overcast days above 17℃ with winds below 5 on Beaufort scale)(Carvell et al., 2017). Transects were the same route each year and selected by a route that passed through each habitat aiming to keep effort as consistent as possible across sites (approx. 20 min walk for each). Plants (except grasses) were identified through randomly placed quadrats (1m x 1m) in each habitat type (such as grass, scrub and woods) (5 repeats for each habitat type). Species richness (total number of species) was calculated for each group (plants, birds, bees, trees and butterflies) and as a total for each greenspace. Wildlife guides were used to identify pollinator species (such as the Big 8 Guide by Bumblebee Conservation Trust and the Big Butterfly Count ID chart by Butterfly Conservation). These methods were conducted on a park level but also for each waypoint area (entrance, café, playground, court, grass pitch, tarmac, formerly managed, hill, water, grassland, tree lined avenue, wood edge and wood). The biodiversity surveys were conducted in good weather between 8 am and 5 pm (typical park use times) in June and July 2019. Repeat of the surveys were conducted at least two weeks apart and the data from the repeats was averaged for each greenspace or waypoint.

Recruitment for guided walks

Participants were recruited through local networks and the associated social media accounts, such as park run, friends of groups, football groups, local organisations, parents' groups, the Better Start Bradford Programme communications, informal mothers' groups and approaching greenspace users to ask if they would participate in guided walks (organised at a later date). To capture diverse views of the greenspaces the walks were conducted multiple times for each greenspace with different user groups (such as friends of group, running club or local mothers' group). Participants were able to sign up for specific dates and times but were also able to request a different time if they were unavailable at the advertised times. The walks were then 'full' when 14 slots were booked as this was the number of smart phones available to lend to participants to take pictures of the waypoints on the guided walk. To ensure appropriate consent for participation, participants were recruited if they were over 18 and not in a vulnerable group. All participants were given £10 compensation for their time (as the walks were a significant amount of time), which was advertised as part of recruitment.

Guided walks

I collected data through guided walks around a standard set of waypoints in each greenspace. These waypoints were selected after site visits to explore a spectrum of waypoints found in greenspaces across the study area and to capture perceptions of communities for the main greenspace for each area of the study area (as identified by community engagement) (Figure 5.2 and Table 5.4). Therefore, participants were different for each guided walk (participants for the first walk differed to those participants in the second walk) and in each greenspace (Horton participants differ to Peel Park) so that a variety of perspectives from different communities were captured across the study area. The guides (myself and a colleague) were the same for every walk.

Participants filled in surveys before, during and after the walk (see surveys and associated research questions in Table 5.10 in the supplementary material). Applying the guided walk method (which has increasingly been used in research) can be a more natural and representative way to collect people's perceptions and thoughts about landscapes compared to showing them pictures, and can break down the barriers between experts and non-experts (Pink, 2007; Scott et al., 2009; Macpherson, 2016; Middleton, 2018). Walking methods can generate more rich and specific spatial data for a landscape compared to sedentary methods, especially as bodily senses respond and change as a person moves through space which is best explored in-situ (Wylie, 2005; Bissell, 2009; Middleton, 2010; Evans and Jones, 2011). Walking methods are often used in urban settings and increasingly used in urban planning (to understand transport or journeys to and from work or school)(Pierce and Lawhon, 2015; Middleton, 2018). I build on previous literature by using a walking methodology within urban greenspaces combined with data for these greenspaces (biodiversity and user quality). Guided walk methodology uses a landscape stewardship lens, to be more inclusive of a range of stakeholders (including local and indigenous knowledge) by including people not only as variables that affect landscapes but also as stewards of the landscape who are involved in the collaborative management and community surrounding the landscape (Ode Sang and Tveit, 2013; Plieninger et al., 2015). Successful application of the landscape lens can inform decisions of multiple stakeholders (such as local community organisations, charities, policymakers, government agencies and private sector stakeholders) to promote multiple outcomes (such as food production, recreation, biodiversity, conservation, cultural and social activities and health and wellbeing outcomes)(Laven et al., 2013; Plieninger et al., 2015). The landscape lens is particularly useful for exploring spaces with multiple societal demands (Plieninger et al., 2015). Therefore, applying a landscape lens through guided walks in urban greenspaces is appropriate as the method involves multiple stakeholders and collecting real-time in-situ changes of perceptions in towards greenspace features and how this relates to multiple-dimensions of the greenspace experience. Involving people in the research by using an inclusive method such as guided walks can facilitate a feeling of inclusion and stewardship towards that landscape, which can influence their attitudes towards conservation and planning (Lokocz et al., 2011). Here, in this study, the participants knew that the data collected from them through the walks would be anonymously processed to inform future greenspace design, decision-making and stewardship (including community involvement through established local groups). Indeed, the European Landscape Convention, encourages the aspirations of local people for landscape features and landscapes to be integrated into the management of landscapes and guided walks are one method to involve the local community (The Council of Europe, 2004; Loupa Ramos, 2010; Ode Sang and Tveit, 2013).

The guided walks were conducted as group (ranging from 3- 14 people) in good weather between 8 am and 5 pm (typical park use times) in June and July 2019. The walks took an average of 1 hour, with a stop at each waypoint in that greenspace (features, Figure 5.2 and Table 5.4) for participants to fill in a form and take any pictures. The surveys pre/post-walk could take up to 15 minutes each but participants tended to speed up as the walk went on as the questions were consistent across all three surveys. Each participant was given a unique ID to maintain anonymity the data and match responses across pre and post walks.

To explore the participants' relationship with nature I used the Nature Relatedness Scale (Nisbet and Zelenski, 2013) and Inclusion of Nature in Self (INS) (Schultz, 2001) tools to obtain measures of nature connectedness (measured Likert low to high scales, 1-5 and 1-7), I also asked about participants' biodiversity knowledge and if they were members of environmental organisations (yes/no). Biodiversity knowledge of a participant was tested through a picture quiz with 3 pictures for each taxon (birds, butterflies and plants)(adapted from Dallimer et al., 2012). Pictures for each taxon varied in difficulty, beginning with common easily identifiable species observed in urban greenspaces to less common species (i.e birds: blue tit, wren, and bullfinch). A score for each group of questions was then added to make a final score with 9 correct answers and a maximum score of 18 (question 1 was worth 1 point, question 2 worth 2 points and question 3 worth 3 points; see quiz in pre-walk survey, supplementary material). Participants were also asked about their satisfaction with the greenspace (Likert scale, low to high: 1-5) and the perceived biodiversity of the greenspace. Perceived biodiversity was ascertained using an adapted method from Fuller et al. (2007) and Dallimer et al. (2012) where respondents were asked how many types of birds, butterflies,w plants and trees lived in the park. Participants were also asked about how they used the greenspace, using the question from the UK government survey on Monitor of Engagement with the Natural Environment (MENE) (Natural England, 2009).

To explore trade-offs or potential win-win features (offering benefits for biodiversity and people) participants were asked to score each waypoint attractiveness and safety (Likert scale, low to high: 1-5), and comment on the features they liked or disliked at each waypoint. Participants could self-report wellbeing before, during and after the walk by answering questions from the Perceived Restorativeness Scale (Likert scale, low to high: 1-5, Hartig et al., 1997 and Nordh et al., 2009).

I compared reported wellbeing, nature connectedness, greenspace satisfaction and perceived biodiversity before and after the walks to test whether the walk around the greenspace had an impact on the participants' perspectives. Demographic data (age, gender and ethnicity) and consent was also collected from participants.

Data analysis

To explore trade-offs between biodiversity, attractiveness, safety and wellbeing I used average scores from the Likert scales across participants for each greenspace walk and compared between the waypoint types. I use thematic narrative analysis to analyse the qualitative data to explore the reasons behind scores given to particular features, the trade-offs and potential for win-win designs (Bryman, 2015). Participant photos were used as examples and to complement the comments from participants about specific features and were analysed as part of the thematic analysis of the qualitative data analysis from free text boxes in the surveys completed during the walk.

To compare the impact of the walk on wellbeing, nature connection and greenspace perceptions (satisfaction and perceived biodiversity) I used non-parametric Wilcoxon Signed-Rank Test on paired before and after scores. I used this non-parametric test as the Shapiro-Wilk Test for Normality showed that the data was significantly different to normal (w= 0.96892, p-value = 0.002). Paired Wilcoxon Signed-Rank Tests were run separately for each greenspace (paired by before and after). As the distribution of the data was significantly different to normal, a Spearman's rank correlation coefficient was used to explore correlations between observed and perceived species richness. Due to the small sample sizes across age, gender and ethnicity it was not possible to give valuable insights from any comparisons, therefore I did not carry out comparisons across these groups.

Figure 5.2. Examples of participant pictures for each waypoint.

5.4 Results

Sample

A total of 75 people participated in the guided walks. The majority of participants were female (68.0%, 32.0 % male) (Table 5.1). For those that gave their age, there was a rage from 18 – 85 years old (Table 5.1). The majority of participants were white or South Asian (58.7% and 34.7%, n= 75) (Table 5.1). Most participants were not part of any environmental organisation or charity (local or national) (no: 70.7%, yes: 29.3%, n= 75) (Table 5.1). The majority of participants used greenspaces for walking (80%, n= 75) and almost half for playing with children (48.0%, n=75; Table 5.1). Only 12% (n= 75) used the greenspaces to watch wildlife (Table 5.1). Biodiversity knowledge was low amongst participants, with the majority scoring less than 60% on the common biodiversity quiz (low: 89.3%; high: 10.7%, n= 75; Table 5.1). The average wellbeing score was medium to high (3.7 ± 0.7 SD, n=74) (Table 5.2). The average connection to nature was high (4 ± 0.7 SD, n= 70) (Table 5.2). Satisfaction was neutral to satisfied (3.7 ± 1 SD, n= 74) (Table 5.2). There was a range in the perceived number of species (average number of bird species: 13.6 ± 11.4 SD; butterfly species: 7.8 ± 8.1 SD; plant species: 72.7 ± 138.2 SD)(Table 5.2).

Greenspaces

The greenspaces included in this study varied in size, quality and species richness (Table 5.3). However, the walks taking place in Myra Shay and Bradford Moor took place in two greenspaces separated by a road to capture a range of features as Bradford Moor Park did not have woodland or wood edge but Myra Shay did. Qualitative data from Chapter 4 showed that participants would often use both parks during a single visit. The species richness for each waypoint type within each greenspace is displayed in Table 5.4. Note species richness may appear unusual, such as high for the café but the cafés in the study area had specific planting within the waypoint such as flowers next to the entrance to the café.

Table 5.1. Demographic information for participants (n= 75)

Category	Count	%
Gender		
Female	51	68
Male	24	32
Total	75	0
Age		
18-30	14	18.7
31-40	17	22.7
41-50	13	17.3
51-60	9	12.0
60-70	15	20.0
71-80	5	6.7
80-90	1	1.3
Did not answer	1	1.3
Total	75	100.0
Ethnicity		
White; English/Welsh/Scottish/Northern Irish/British	44	58.7
South Asian (Indian, Pakistani or Bangladeshi)	26	34.7
Any other ethnic or mixed/multiple ethnic backgrounds	5	6.7
Total	75	100.0
Are you a member of an environmental organisation		
No	53	70.7
Yes	22	29.3
Total	75	100.0
Use of greenspace		
Walking	60	80.0
Playing with children	36	48.0
Relaxation	21	28.0
Running	15	20.0
Informal games and sport	15	20.0
Picnicking	13	17.3
Walking a dog	10	13.3
Wildlife watching	9	12.0
Work	5	6.7
Off-road biking	4	5.3
Appreciating scenery from your car	2	2.7
Pitch and put	1	1.3
Research	1	1.3
Learning and visually impaired walk	1	1.3
Litter picking and leading a walking group	1	1.3
Organized sports	1	1.3
Events	1	1.3
Feeding birds	1	1.3
Foraging	1	1.3
Ecological knowledge		
Low	67	89.3
High	8	10.7
Total	75	100.0

Table 5.2. Participant wellbeing, satisfaction, nature connection and perceived species richness before and after the guided walk.

		Average	SD	Min	Max
Wellbeing	before	3.7	0.7	1.2	5
	after	3.9	0.8	1	5
Satisfaction	before	3.7	1.0	1	5
	after	3.8	0.9	1	5
Nature Connection	before	3.8	1.2	1	5
	after	3.5	1.6	1	5
Perceived species richness	before	79.4	137.4	0	1030
	after	160.8	575.3	0	5015
Perceived bird species richness	before	13.6	11.4	1	50
	after	11.9	12.2	2	50
Perceived butterfly species richness	before	7.8	8.1	0	50
	after	7.0	7.8	0	50
Perceived plant species richness	before	71.7	138.2	0	1000
	after	154.0	594.5	3	5000

Table 5.3. Greenspace characteristics of user quality, size, species richness (total present in the whole greenspace collected via transects and averaged across waypoints) and perceived species richness.

	Quality (NEST)	Size (ha)	Total SR	Plant	Birds	Butterflies	Average species richness (SD)	Perceived species richness (SD)
Bowling	116.8	32.6	84	65	14	5	7.3 (4.1)	241.2 (791.5)
Horton	106.4	16.3	60	41	13	6	6.1 (3.2)	71.4 (85.0)
Myra Shay & Bradford Moor	97.1	6.4	56	38	14	5	7.3 (4.1)	19.8 (11.8)
Peel	114.9	26.8	52	35.5	13	4	8.2 (2.5)	181.1 (264.4)

Table 5.4. The waypoint present in each greenspace and the species richness of each waypoint. Note the perceived species richness was collected on a park level and not comparable on a waypoint level.

Greenspace	Waypoint in order	Species richness
Bowling	Café	10
	Court	0
	Wood edge	12.5
	Wood	9
	Grass	4.5
	Tree avenue	8.5
	Tarmac	6.5
Horton	Entrance	4
	Playground	7.5
	Formal	6
	Water	3.5
	Grass	7.5
	Court	0
	Scrub	7
	Tree avenue	7.5
	Wood	11.5
Myra Shay & Bradford Moor	Playground	5.5
	Pitch	4
	Tarmac	5.5
	Tree avenue	9
	Water	3.5
	Scrub	12
	Grass	4.5
	Wood	14.5
Peel	Entrance	10.5
	Café	7.5
	Water	5
	Grass	5.5
	Grass (hill)	10.5
	Scrub	10

Research Question 1: How do people perceive different greenspace features with reference to the following dimensions of experience: attractiveness, safety, wellbeing, nature connection and biodiversity?

Safety

A key aspect for safety was open space, being close to features such as roads or entrances, vantage points and having other users in the area of the greenspace (Figure 5.3, Table 5.5). Being away from busy roads and in quiet places also added to higher safety (Table 5.5). The features that scored high on safety were grass, water and tree avenue, mirroring the preference for open and quiet aspects highlighted by participants (Table 5.5 dimensions, Figure 5.3). Grass hills were scored as safe by 40% of the participants (n= 6 of 15)(Table 5.7). Safety had a weak positive association with wellbeing, attractiveness and nature connection (ρ= 0.49, 0.46, 0.43) (Table 5.6).

Attractiveness

When exploring comments on what participants perceived as attractive there was consensus that a variety of vegetation, predominantly trees and a general greenness was attractive. Flowers in general were popular features, in addition to formal planted areas were rated as attractive by all participants (100%, N= 16 of 16) (Table 5.5, Figure 5.4). Grass, grass hills and pitches were scored as attractive by 80% of participants (80.4%, n= 45 of 56; 80.0%, n= 12 of 15; 80.0%, n= 4 of 15) (Table 5.7). Areas with a view were seen to be attractive, this often involved being on a hill looking across the Bradford area to hills, trees, the city or historical buildings. Within greenspaces themselves historical features (statues, bridges or signs) and local culture or art contributed to as space being perceived as attractive (Table 5.5, Figure 5.4). Open areas and space were also seen as attractive (Figure 5.4). A feeling of naturalness and wildlife (predominantly birds but also insects, especially pollinators) were also highlighted as attractive. Paths were also seen as attractive features. Opportunities for play (inside/outside of the playground) were also seen as an attraction to the greenspace. Attractiveness had a weak positive correlation with areas perceived as wild, safe areas and areas with higher nature connection recorded (ρ= 0.32, 0.46, 0.46) (Table 5.6). Although participants highlighted diversity of trees, flowers and wildlife as important, there was no correlation between attractiveness and the species richness (ρ=0.24) (Table 5.6). This lack of relationship could be tied to the way I measured biodiversity (spontaneous vegetation was the dominant vegetation). However, attractiveness and wellbeing had a moderate positive correlation (ρ = 0.73) (Table 5.6).

Wellbeing

Comments from participants for features scoring high for wellbeing were similar to those for attractiveness. Partly due to the data collection method which asked participants to enter thoughts about the area into an open text box. This helps highlight features with high scores across the dimensions. Participants highlighted green features in their comments and pictures, such as plants, flowers and trees (Figure 5.5, Table 5.5). A sense of naturalness was also discussed by participants, with appreciation for areas that felt more natural or away from urban features (Figure 5.5, Table 5.5). For example 70% (n= 14 of 20) scored wood edge as high for wellbeing (Table 5.7). Opportunities for play or picnics were also included in participant comments on areas with high scores for wellbeing (Table 5.5). The café was particularly highlighted by one participant as being a space used for wellbeing as a place they can meet friend and seek advice (Table 5.5). Wellbeing had a moderate positive correlation with attractiveness and areas with high nature connection scores (ρ = 0.73, 0.61, Table 5.6). Wellbeing had a weak positive relationship with areas participants perceived as safe or wild (ρ= 0.49, 0.44, Table 5.6).

Wildlife, species richness and nature connection

Trees were an important feature for areas that were scored high for wild, for example wood edge was scored as wild by 85% (n=17 of 20) of participants (Figure 5.6, Table 5.7). Participants identified areas with lower human intervention (such as letting things grow taller or thicker or lots of self-seeding vegetation)(Table 5.5). Vegetation, 'greenness' and long grass in particular was highlighted as an indicator of a wild area, with some participants using the term overgrown. For example, 63.0% (n= 29 of 46) scored scrub as wild (Table 5.7). Participants also stated that these wilder areas were more likely to support or attract wildlife such as birds, butterflies, insects and pollinators. Seeing and hearing animals was also an indication of more wild areas, especially bird song. Wood edge, pitches, water, formal planting, scrub and wood scored high for nature connection (Table 5.7). Open space was also associated with areas scoring high for wild. Wild scores had weak positive correlation with wellbeing, attractiveness and nature connection (ρ=0.44, 0.32, 0.27) (Table 5.6). Wild scores had very weak positive correlation with species richness (Table 5.6). Perceptions of wildness may be driven by the visual composition such as flowers, density or height of vegetation rather than species richness. There was no significant correlation with safety (ρ= 0.09), which is reassuring that it is possible to have high species richness without negatively impacting safety (Table 5.6). This relationship may be driven by similar perceptions of dense vegetation being less safe, as opposed to being driven by species richness in that area.

Table 5.5. Themes and example comments from participants under the dimensions of perception; safety, attractiveness, wellbeing and wildlife. The enabling features that participants identified as features that would encourage their use of that area again are also coded with the same themes and included below.

Theme	Subtheme	Safe (n= 27)	Attractive (n= 68)	Wellbeing (n= 58)	Wildlife (n= 62)	Enabling features (n= 64)	Example comments
	Vegetation		99	64	25		'Lovely long wild grass and trees', 'lots of different trees and plants and can be in the middle of them', 'moss and algae on the tree trunks is beautiful', 'nice spot for a picnic under the trees', 'long grass for wildlife- looks good too', 'some grass has been left unmown, to attract insects'
	Flowers		33	11	5	4	'Beautiful daisies growing naturally', 'purple flowers', 'I like the lawn overgrown with clover and buttercups', 'many flowers, can see butterflies and bees and nature use it'
	Woodland					9	'Woodland walk', 'woodland'
	Trees				45	14	'Fab path of tall trees', 'trees surrounding area, looks stunning', 'it is a woodland so obviously wild', 'lots of trees, fab for wildlife', 'feels natural, variety of trees and open'
Natural features	Wildlife		11	6	16		'Love the pond and ducks and ducklings', 'can see animals', 'many flowers, can see butterflies and bees and nature use it'
	Birds		11	9	12	3	'The island provides a habitat for birds', 'a variety of birds', 'ducks and ducklings', 'can see a magpie and flowers growing', 'bird song',
	Invertebrates				7		'It is a neat area but the bug area introduces a wild element', 'mostly man-made but there is a bug hotel and lots of flowers to attract pollinators', 'overgrown plants make you think plenty if mini-beasts would inhabit'
	Water		5	3	7	12	'The birds at the water in the pond', 'water, trees, wildlife all present', 'manmade pond', 'the pond is lovely and clean'
	Rocks		3	2			'Love the borders and rockery', 'lake with interesting rocks in background'
	Natural		19	17	8		'At one with nature', 'I prefer the wild area to the perfectly even space', 'the area is very green which is nice in the city to get away from large brick structures', 'I like it when nature

							is left to itself especially as I'm in the city all the time', 'Like the freedom, plants have to grow their own way'
	Management		3		48	6	'Well-maintained and attractive', 'pretty plants, nice smell, well kept', 'formal lawns and gardens', 'wild in places, less weed killer more bird song', 'no human interference', 'lots of uncut grass, brambles and wild flowers'
	Overgrown				6		'It is overgrown', 'overgrown brambles', 'overgrown grass'
	Sky				2		'The blue open sky and lots of mature trees', 'the sky'
	Vantage point	7					'High', 'area visible from other angles of the park'
	Open space	23	19	10	8	9	'Open - nothing to attract bad people', 'open, multiple exits', 'it is open and inviting', 'open area but surrounded by trees',
	Space		7	2			'Big greenspace'
	Green area				6	5	'Lots of greenery, nature', 'open grass area', 'greenspaces', ''love green'
	Views		28	16	2	2	'the view is breathtaking, 'the view is amazing', 'nice clear view of Bradford in the background'
Less natural features	Paths		11	6		5	'Can see a path, lures you in', 'like, impressive view of trees either side of path', 'I love the potential for exploring this part of the park, I usually stick to the other paths', 'pathway into woodland', 'wide open path with nicely trimmed bushes', 'footpaths for exercise'
	Local history/art		14	5		3	'Shows a cultural feature sundial', 'historical monument', 'old steps, pond, water fountain, lots of old but nicely kept monuments', 'the pond area and bridge',
	Café		4	4		1	'The cafe is a safe place where people meet friends and get advice if needed'
	Tarmac		2	2		1	'I quite like the formal nature of this area, it will lend itself well to community events', 'would make a good performance venue', 'old rose garden as a performance area'
	Urban proximity	17			4		'It is very near the entrance so am able to get out easily', 'quiet away from traffic', 'very close to nature'
	People	5					'People around', 'quiet but people around', 'it is quite a busy part of the park'

	Road safety	4					‘No roads nearby’, ‘away from houses and roads’, ‘open aspect, no traffic’
	Maps/signs					1	‘Maps and signposts’
	Bench					2	‘Bench’, ‘clean benches’
	Lighting	1					‘Lights safety’
	Formal planting					7	‘Flower beds’, ‘flower beds - which look great, especially in bloom’, ‘flower garden’
Senses and/or sense of place	Quiet	4	10	8		5	‘Peaceful, quiet, safe’, ‘quiet peaceful, safe and clean’, 'love this part of the park. So relaxing from a hearing and visual point of view’, ‘Access to area of solitude’, ‘open area is relaxing’, ‘the hidden areas’, ‘quiet areas’, ‘the wooded area - very peaceful’, ‘quiet areas in which to sit’, ‘quiet safe inviting area’
	Senses		3	3	3		‘Pretty plants, nice smell, well kept’, 'clean fresh air', ‘love this part of the park. So relaxing from a hearing and visual point of view’, ‘can hear more wildlife hear’, ‘lots of bird song heard, wind blowing strongly as we are up high’, ‘great, love the natural feel, bird song, butterflies’,
	Colour		2	1			‘Like the colour, variety of flowers’, ‘like the amount of flowers and diversity/colour’, 'I love the differing colours of green’
	Comfort	2					‘I feel very comfortable here’, ‘this is my area of the park where I feel most comfortable’
Uses of greenspace	Exercise		3	2		5	‘Tennis courts good for children and adults’, ‘where I walk my dogs’, ‘exercise equipment’
	Play		11	5		10	‘The play area of the park is the reason for coming to this part of the park’, '‘large play area for kids’
	Bike					3	‘Bike track’
Total		**63**	**298**	**176**	**204**	**108**	

Figure 5.3. Examples of participant pictures of features that scored high (4-5 Likert) for safe

Table 5.6. Correlation matrix (Spearman's rank correlation) between dimensions of greenspace perceptions and associated p values.

	Wild		Wellbeing		Attractive		Safe		Nature Connection		Species Richness	
	ρ	p	ρ	p	ρ	p	ρ	p	ρ	p	ρ	p
Wild	1.0		0.4	<0.01	0.3	<0.01	0.0	0.4	0.4	<0.01	0.2	<0.01
Wellbeing	0.4	<0.01	1.0	<0.01	0.7	<0.01	0.4	<0.01	0.6	<0.01	0.2	<0.01
Attractive	0.3	<0.01	0.7	<0.01	1.0	<0.01	0.4	<0.01	0.5	<0.01	0.2	<0.01
Safe	0.0	0.4	0.4	<0.01	0.4	<0.01	1.0	<0.01	0.4	<0.01	0.1	0.04
Nature Connection	0.4	<0.01	0.6	<0.01	0.5	<0.01	0.4	<0.01	1.0		0.1	0.17
Species Richness	0.2	<0.01	0.2	<0.01	0.2	<0.01	0.1	0.04	0.1	0.17	1.0	

Figure 5.4. Examples of participant pictures of features that scored high (4-5 Likert) for attractiveness

Figure 5.5. Examples of participant pictures of features that scored high (4-5 Likert) for wellbeing

Figure 5.6. Examples of participant pictures of features that scored high (4-5 Likert) for wild.

Table 5.7. Summary of the features average score (1-2 Low, 3 Medium and 4-5 High) and the percentage of participants (n =75) that scored that features as high (4-5 on Likert) and note that for nature connection high was a score of 5-7. For species richness the categories are low 0-4, medium 5-7 and high 8-12.5 species).

	Attractive	%	Safety	%	Wellbeing	%	Wild	%	Visit Again	%	Average of nature connection	%	Average species richness
Café	M	58.8	M	2.8	M	30.6	L	17.1	M	57.1	M	8.3	H
Court	L	21.6	L	2.7	L	10.8	L	13.5	L	32.4	M	10.8	L
Entrance	M	48.5	M	9.1	L	15.2	L	3.0	M	45.5	M	6.1	H
*Formal planting	H	100.0	M	6.3	M	12.5	L	18.8	H	93.8	H	43.8	H
*Grass	M	80.4	M	23.2	M	37.5	M	39.3	M	74.1	H	36.4	M
Grass (hill)	H	80.0	M	40.0	M	53.3	L	26.7	M	66.7	H	20.0	H
*Pitch	H	80.0	M	20.0	M	40.0	M	40.0	M	40.0	H	60	M
Playground	M	45.7	M	13.9	M	22.2	L	11.4	M	55.6	M	14.3	H
*Scrub	M	45.7	M	19.1	M	38.3	M	63.0	M	41.3	H	41.0	H
Tarmac	M	84.0	M	13.5	M	35.1	L	22.2	M	56.8	H	32.4	H
Tree avenue	M	65.4	M	16.1	M	34.5	L	16.4	M	67.3	M	32.7	H
Water	M	47.1	M	21.6	M	37.3	L	34.0	H	64.0	H	48.0	M
*Wood	M	66.0	M	14.3	M	51.0	M	58.3	M	68.8	H	40.4	H
*Wood edge	H	63.2	M	5.0	M	70.0	H	85.0	M	80.0	H	61.1	H

Research Question 2: Are there features that score high across all the dimensions and offer win-win opportunities?

After exploring participants' perceptions of greenspace features and areas in relation to safety, wellbeing, attractiveness and biodiversity, I aimed to identify features that were win-wins. It is more difficult to find a win-win feature through quantitative data alone, as many participants scored features as neutral and expressed in the qualitative data what would improve their perceptions and scores. Some features did score high for attractiveness (formal planting, grass hill, pitches and wood edge), wild (wood edge), revisiting an area (formal planting) and nature connection (formal planting grass, grass hill, pitch, scrub, tarmac, water, wood and wood edge) (Table 5.5). While other features scored low for attractiveness (court), wellbeing (court and park entrance), safety (court), wild (café, courts, entrance, playground, tree avenue, tarmac, tree avenue and water) and revisiting the area (court) (Table 5.5). Features that were scored as high or medium and did not have a low score across the dimensions were grass, pitch, scrub, wood and wood edge (Table 5.5). These features, along with formal planting (which only scored low for wild), could form the foundation for win-win features in urban greenspaces with participants identifying benefits for people and nature (these areas also had medium to high species richness). Qualitative data from participants did however, show that a variety of features is important so having features with low species richness such as courts is important as long as these features do not dominate the greenspace and there are areas for wildlife.

Grass

Grass features, particularly if on a hill, scored high for attractiveness, wellbeing, nature connection, species richness and visiting again but was neutral for safety. **Pitches** have similar pattern but dipped to low score (2) for species richness, most likely due to being a similar feature to grass areas but pitches are more likely to be mown and aren't managed for biodiversity. **Scrub** features scored high for nature connection and species richness but neutral for visiting again, attractiveness, wellbeing and safety. The scrub type of feature is one where participants identified the value for nature but highlighted a risk for safety due to lack of visibility or low usability of the area.

Water

Water features scored high for visiting the area again and nature connection but low for species richness and neutral for well-being and safety (Table 5.7). These scores are reflected by all participants. The impact of low-quality water could be pulling the overall score down. Based on qualitative data, participants highlighted good quality water features (and the associated wildlife) as attractive and good for their wellbeing but low-quality water features as having the opposite effect.

Trees

Tree avenues were highlighted as attractive areas and scored high for visiting again, nature connection and species richness but scored neutral for wellbeing and safety (Table 5.7). The features were often along paths or near exits and entrances, which have been highlighted as good features for safety. However, participants also stated that motorbikes and vehicles would enter near one of the tree avenues, which may impact the safety score for this feature. Participants recognised the value of **wood edge** habitat for species richness and high nature connection. Participants also indicated that they'd like to visit the area again and found it attractive and scored it high for wellbeing, highlighting relaxing sounds or bird song. However, the tree-edge feature scored neutral for safety and often participants said they were nervous of entering the associated woodland which did not have a path and had low visibility. A very similar pattern can be seen for **wood** features (Table 5.7).

Less natural features

When exploring the less-natural features in the spaces, the **entrance** was neutral for all categories with little overall pattern emerging (Table 5.7). However, particular features at entrances such as historic signs, art installations, cafes or formal planting were highlighted as attractive features in the qualitative data from participants. A similar pattern is found for **cafes**, which have been highlighted as an important enabling feature of use of a space and for wellbeing and can support biodiversity through intentional planting or interventions such as insect hotels or bird boxes. These biodiversity interventions were often observed in greenspaces with 'friends of groups', who often supported the café logistics and day-to-day running. Participants recognised that **courts** were low for biodiversity and expressed neutral attitudes toward them for safety, attractiveness, visiting again and wellbeing (Table 5.7). However, they were recognised as an opportunity for exercise. **Tarmac spaces** that had previous use or temporary use (such as hosting fairs or pop-up farms) were neutral across most dimensions but high for nature connection, they were often surround by scrub or trees (Table 5.7). Areas that were **formally planted** were rated highly for nature connection, visit again, attractive and wellbeing but neutral for safety and species richness. The safety score may have been impacted as the example of formal planting was enclosed with lower visibility. **Playgrounds** were scored as neutral for every dimension, but from qualitative data and observation data (Chapter 4) this was the most used feature in the park (Table 5.7).

Enabling use of areas within a greenspace

Participants were asked 'did you notice any features along the walk that would attract you to use that area of the park? If yes, what features were these?' Single or small groups of trees or water were the most attractive features for encouraging use of an area of a greenspace. The play areas were also identified as enabling features. Woodland and open space were also popular. Maintained areas such as formal planting and mown grass were also identified as enabling features (Table 5.5).

Research Question 3: How does actively thinking about greenspace features while walking through a greenspace influence perceptions of that greenspace?

Wellbeing, perceived species richness, satisfaction and nature connection

Overall, participants had higher wellbeing scores after a walk in the greenspace (before: 3.7 ± 0.8 vs after: 3.9 ± 0.8, p= 0.02, Table 5.2). There were no significant differences in satisfaction, nature connectedness, or any measures of species richness (p>0.05 in all cases, Table 5.2). Before the walk, there was a significant negative correlation between observed and perceived butterfly species richness (Spearman's ρ= -0.34, p<0.001) and no other significant relationships. After the walk, there was a significant weak positive correlation between the observed species and perceived species for the total species (ρ= 0.24, p=0.03) and plant species (ρ= 0.23, p=0.05), and a weak negative correlation between observed and perceived butterfly species richness (ρ= -0.23, p=0.05). However, there was no significant correlation between observed and perceived bird species richness after the walk (Spearman's ρ= -0.23, p=0.07).

Participant reflections after the walk

Participants were asked 'how do you feel about the journey of today's walk? Have you been affected in any way?'. In response, participants said that they enjoyed the walks, often saying that they found new areas or new perspectives (28.0%, n=21 of 75) and that they felt calm or relaxed (10.7 %, n= 8 of 75) (Table 5.8). Others said it was nice to rediscover or be reminded of the different elements of the local greenspace (4%, n= 3 of 75) (Table 5.8). Noticing nature was also highlighted as influencing participants (5.3%, n= 4 of 75, Table 5.8). Other participants said that they felt the same and there were no impacts on them (8%, n= 6 of 75; Table 5.8). However, some participants said they felt sad or had negative reflections after noticing litter or decrease in quality of the greenspace (9.3%, n= 7 of 75; Table 5.8).

Table 5.8. Examples of participant comments about how they felt about the guided walk (n = 75).

Comment type	N	Examples
Enjoyed	21	Really enjoyed my walk and observations made, made me think about all the features’, ‘enjoyed as discovered new areas’, ‘enjoyed it, enjoyed being with other women’
New areas or perspective	13	‘I became aware of how large it is and diverse areas’, ‘it has made me see different areas of the park which I don't stop at’, ‘Fantastic, got to explore different areas of the park’, ‘good eye opener of different areas in the park’
Sad or negative reflections	7	‘The walk has given me an opportunity to really stop and look closely in how I use the green space around me, it confirmed to me how much needs improving’, ‘sad to see the state of the pond and a rat eating disused rubbish’, ‘this was my childhood park but a shame too much has gone downhill’, ‘I noticed it is very dirty’, ‘feel sad by all the litter’
Restorative	8	‘Uplifted, rested, refreshed’, ‘I feel more relaxed and less scared to be here on my own’, ‘Nice and calming’, ‘I feel more relaxed and enjoyed the dogs company’, ‘Loved it, refreshing and enjoyed being with other mum's [on the walk]’
Same	6	‘A pleasant walk in the park no lasting affectations’, ‘the same’
Nature	5	‘Really lovely walk in a beautiful park. Will go into the wilder bits now’, ‘it was a nice walk observing the nature surrounding us’, ‘noticed more nature than previously’
Grateful or rediscover	3	‘Enjoyed it, forgotten how nice park was’, ‘I feel even more attached to the park’, ‘makes one appreciate the wonderful park we have close to home’

Use of greenspace after a biodiversity-focused walk

Participants were asked to rate the following statement and offer additional insights as to why ‘I will use this park differently now that I have been on this walk. If so, how?’. After the walks, participants (20%, n= 15 of 75; Table 5.9) said they would use new areas of the greenspace or more frequently (9.3%, n= 7 of 75; Table 5.9). Participants said they’d use the greenspace for exercise such as walking (17.3%, n = 13 of 75) or play (8%, n = 6 of 75), taking note of nature (6.7%, n= 5 of 75), go on picnics (5.3%, n= 4 of 75), use the café (4.0%, n= 3 of 75) and for wellbeing (4.0%, n= 3 of 75; **Table 5.9**Table 5.9). Some participants stated that they would continue using the greenspace the same (2.7%, n= 2 of 75) and one said they would not return (1.3%, n= 1 of 75, Table 5.9).

Table 5.9. Example comments from participants on how they would use the greenspace differently after the guided walk (n= 75).

Comment type	N	Examples
New areas	15	'Try different routes around it', 'Walk in different areas', 'try different routes', 'see more and new spaces of the park'
Exercise	13	'Bike ride and walks', 'bring my kids to cycle and have picnic'
Frequency	7	'This was our first visit will definitely come back', 'use it more'
Play	6	'I will bring my kids family and friends over summer and for a life change', 'bring my kids here'
Nature	5	'Discover more about nature, want to take care of it', 'I will go to the wilder areas we normally miss out', 'take more appreciation of nature', 'will visit the lake area'
Picnic	4	'bring my kids to have a picnic'
Café	3	More likely to come for a lunchtime picnic, or use the cafe
Wellbeing	3	'Slow down and pay attention', 'I think the rustling trees and chattering of birds will be a good incentive to return and maybe have much lunch and maybe do a drawing', 'For get- together with family and friends in areas not normally used'
Same	2	'Same use'
Not return	1	'Not sure if I come back'

5.5 Discussion

Common methods for exploring the relationship between greenspaces and health and wellbeing can leave gaps in understanding how people use greenspaces, the parts of the greenspace they use, why they use these areas and the role biodiversity plays. I show that there are trade-offs between aspects of biodiversity and safety, attractiveness, nature connection and wellbeing across different features of a greenspace. For example, grass fields scored highly for attractiveness, wellbeing, nature connection, species richness and visiting again but neutral for safety. Features that did not have a low score across the dimensions were grass, pitch, scrub, wood and wood edge and could be seen as a foundation for win-win interventions with benefits for people and nature. Note that formal planting scored high across all dimensions but scored low for wild but these features have been shown to offer benefits for biodiversity and people and scored high for visiting again, therefore, this feature is included in the win-win features. A guided walk in the park where participants were asked to comment on natural features had a significant positive impact on participant wellbeing and improved participants' ability to accurately estimate species richness overall, trees and butterflies but did not improve ability to accurately perceive bird species. There was no significant impact recorded in the quantitative data for park satisfaction and nature connection for the sample. However, qualitative data did show that participants enjoyed the walks, found new areas and would use the greenspace differently (such as notice wildlife more). Here I show that biodiversity has a relationship with how people perceive a greenspace, acting as either a barrier or enabler to use depending on management. A variety of park features can offer benefits across greenspace users and increasing biodiversity (or accessibility of more biodiverse areas through features such as paths) could increase use of that part of a greenspace. Most importantly, it is possible to have high biodiversity and create safe and attractive areas that facilitate nature connection and wellbeing. Here, I highlight features that could be added or enhanced in urban greenspaces with little public opposition as they are perceived as attractive, and encourage use without negatively impacting safety. Management of these features can also reduce maintenance costs, which is key in an environment where local government has restricted resources (O'Sullivan et al., 2017).

Balancing trade-offs between biodiversity and other greenspace dimensions

When exploring trade-offs, it was clear that it is possible to have high species richness without compromising other dimensions because no features were scored as unsafe. However, I recognise by design the methods involved a group walk and some features might have been scored as unsafe if the participant was present by themselves or at night. The weak positive association between safety and wellbeing, attractiveness and nature connection shows that the trade-offs around safety - although very valid and real – are hard to study with quantitative methods, and richer data was gathered through qualitative methods. The quantitative data would imply safety is not a driving force for use, but qualitative data showed that it was a key factor in determining whether an individual used a greenspace or particular features within. Features with medium to high species richness (grass, pitch, scrub, wood and wood edge) also scored medium to high for attractiveness, safety, wellbeing and nature connection. Wild features can also support wellbeing, attractiveness and biodiversity by creating habitats rich in wildflowers and a variety of colours. Previous studies have found areas with denser and/or more diverse vegetation, trees, water and higher diversity of colour to be attractive, at times even preferred and can enrich wellbeing (Schroeder, 1982; Schroeder and Anderson, 1984; Hands and Brown, 2002; Bjerke et al., 2006; Van den Berg and Koole, 2006; Nordh et al., 2009; Lindemann-Matthies et al., 2010; Nordh and Østby, 2013; Weber et al., 2014; McMahan et al., 2016; Hoyle et al., 2017; Fischer et al., 2018a: Harris et al., 2018; de Bell et al., 2018; Hoyle et al., 2019; Wang et al., 2019; Mouratidis, 2019).

However, these features require careful management to maximise benefits for people and nature and maintain safety. For example, participants indicated that dense and low-use wood features were perceived as unsafe due to the potential for antisocial behaviour and lack of visibility (Burgess, 1995; Jorgensen et al., 2002; Bell et al., 2003; Jorgensen and Anthopoulou, 2007; Milligan and Bingley, 2007; Nisbet and Zelenski, 2013; Jansson et al., 2013; Gatersleben and Andrews, 2013; Sreetheran and van den Bosch, 2014; Mouratidis, 2019). Alternatively, low density undergrowth in urban woodland and open areas can feel safer (Schroeder and Anderson, 1984; Jorgensen et al., 2002; Jansson et al., 2013).

It is important to have a mixture of densely vegetated and more open areas in the park, participants expressed appreciation of open space and views and that they felt safe and that these spaces offer opportunities for gatherings and activities such as informal games and picnics. This is supported by the literature that greenspace users perceived open areas with far-reaching views as safe, especially as they feel they can identify or anticipate danger easier in an open area (Jorgensen et al., 2002; Jorgensen and Anthopoulou, 2007; Gatersleben and Andrews, 2013; Qiu et al., 2013). The spatial arrangement of these features can have a greater influence on perceptions of safety compared to the vegetation type (Jorgensen et al., 2002; Mouratidis, 2019). The relationship between edge features and enclosed spaces and vegetation type is complex. However, Jorgensen et al. (2002) found that urban woodlands with no understorey but with flowers were preferred overall and perceived as safest (when even compared to woodland with closely mown grass). Therefore, not only particular features but also the spatial arrangement of features can influence preferences and safety. This study supports this finding that certain natural features (formal planting, grass, pitch, scrub, wood and wood edge) can be preferred and reduce trade-offs between safety, attractiveness and biodiversity.

However, one potential trade-off remains when considering a greenspace as a whole. Participants expressed wanting to use more species-rich natural areas such as the woods but only if specific changes were made, such as paths, clearing vegetation to improve visibility and an element of human management. These interventions may reduce biodiversity by clearing vegetation but careful management could maintain these areas to support biodiversity and people (such as the flower understory features in Jorgensen et al., (2002). Or an alternative way to approach areas like woods or scrub, that have low or no use by people, is to actively manage those areas for biodiversity instead by applying a land-sparing approach to greenspace (Lin and Fuller, 2013). A land-sparing approach to greenspace is where urban developments are based on large wildlife-friendly gardens in low-density housing (land sharing) or where higher-density housing in the same total area allows larger spaces for nature conservation to be carried out (land sparing)(Collas et al., 2017).

Taking a land sparing approach on a city-wide level could help mitigate against some of the impacts of urbanisation (i.e. larger intact habitat) on biodiversity (Lin and Fuller, 2013; Beninde et al., 2015; Collas et al., 2017). Beninde et al. (2015) suggest that sites larger than 50 ha are necessary to prevent a rapid loss of area-sensitive species in urban areas (alongside habitat patches and corridors). This approach could potentially offer greater restorative value through larger greenspaces and spill over of biodiversity areas to other parts or the greenspace and city. However, in Chapter 4 I found no spill over of biodiversity from urban greenspaces to the surrounding streets in the study area. Furthermore, literature shows that even regular contact with small spaces can be beneficial for health and wellbeing, and it is particularly important to be close and convenient to allow for everyday exposure (Natural England, 2010; Rupprecht and Byrne, 2014; Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Lovell et al., 2020; Dobson et al., 2021). In fact, small greenspaces with particular features (such as water) can have similar restorative value to large parks, and some of the highest restorative value (Nordh et al., 2009; Nordh and Østby, 2013). These findings demonstrate the restorative value of small greenspaces, and that large greenspaces don't automatically hold high restorative value. There is opportunity to increase the restorative value of urban spaces through increasing the number, quality and distribution of small greenspaces (Nordh et al., 2009). A land sparing approach may neglect these smaller spaces. However, increasing use of these natural features within large greenspaces can promote wellbeing so land sparing approach could be beneficial if it increases quality and biodiversity. Some of the participants were unaware of areas that are more natural and said they would revisit these new parts of the greenspace after discovering them on the guided walk. A specific recommendation for practice would be to use signs and trails to move people through a range of features in a greenspace, especially to more natural areas which may be overshadowed by other features such as open lawns and playgrounds (Turkseven Dogrusoy and Zengel, 2017; Meyer-Grandbastien et al., 2020). These more natural features can offer great wellbeing benefits, especially if there is a more heterogeneous landscape (Nordh et al., 2009; Nordh and Østby, 2013; Weber et al., 2014; Hoyle et al., 2017; Harris et al., 2018; Hoyle et al., 2019; Wang et al., 2019; Meyer-Grandbastien et al., 2020). Further research could explore the features and how the spatial layout the features are perceived in greenspaces of different sizes, the greenspaces in this study were of similar size so do offer insight into this question.

Having shown participants these more natural areas, they expressed a desire to use them and learn more about them. Participants also recognised their importance for biodiversity, which was seen as an additional attraction to visit that area again. Therefore, participants expressed wanting to maintain the biodiversity alongside improvements to enable their use of these areas. A specific recommendation for practice would be to install features that have a low impact on biodiversity (such as paths, benches and suitable lighting) while maintaining relevant features for biodiversity (Reed et al., 2008; Shores and West, 2010; Besenyi et al., 2013; Van Hecke et al., 2017). Higher biodiversity knowledge can influence perceptions and preferences of biodiversity features (Ode Sang et al., 2009; Gundersen and Helge Frivold, 2011; McMahan et al., 2016; Hoyle et al., 2019). For example, (Gundersen and Helge Frivold, 2011) found that deadwood was more appealing to those who understood the ecological benefits compared to those that did not understand. Another example is a study of 2,000 people in 19 European cities that found a preference for vegetation with a tidy appearance but the study also found a general support for converting lawns into meadows to support urban biodiversity conservation if this value was communicated to participants (Fischer et al., 2020). Therefore, another recommendation is to install signs to educate greenspace users about the biodiversity there and why particular management choices were made (dead wood and no mowing areas). For example, installing signage improved acceptability of meadow plots, especially with relation to increasing tolerance for their 'untidy' appearance in winter (Southon et al., 2017). This was especially important to avoid the appearance of messiness or neglect, that is often associated with wilder/low management features which can act as a signal for antisocial behaviour and act as disservice (Wilson and Kelling, 1982; Kaplan and Kaplan, 1989; Bixler and Floyd, 1997; Hands and Brown, 2002; Lyytimäki et al., 2008; Escobedo et al., 2011; Qiu et al., 2013; Birch et al., 2020; Marselle et al., 2021). Some of the negative perceptions can be addressed through management that display 'cues to care' that reduce the negative signals by signalling care and intentional decisions about a space (Nassauer, 1995; Hands and Brown, 2002). 'Cues to care' in an urban greenspace could include; fences, flowers, shrubs, mown lawns, lawn ornaments, trees in rows, rock features, water and bird boxes (Nassauer, 1995; Hands and Brown, 2002). Fischer et al., 2020 suggest that a mosaic of conventionally and biodiversity-friendly managed areas could help satisfying divergent expectations toward greenspaces by balancing tidy and natural features within the greenspace. Fischer et al., 2020 specifically suggest that grass or meadow areas are accompanied by mown trail edges to give paths a cared appearance and the establishment of mowing strips that enhance accessibility of grassland areas to avoid the impression of neglect of wild elements and offer 'cues to care'. Lampinen et al. (2021) also found that participation in nature related activities increased support for more biodiverse management decisions such as converting mown lawn into tall grass. More frequent visits and having multiple uses of urban greenspace were positively related to a higher acceptance of biodiverse habitats (Fischer et al., 2020). Therefore, a variety of educational and nature-based activities could be run alongside installation of signs about the biodiversity features to increase use, visits and number of uses.

Enabling features of greenspaces

The results from this chapter align with those from the participant-led walks in Chapter 4: natural features were valued, and if of a high quality, are perceived as enabling features with a particular preference for trees, woods, flowers, rocks, water and birds. Participants expressed the same pattern of preference for intermediate levels of vegetation and biodiversity, such as half-open areas of grass and trees (Qiu et al., 2013; Lindemann-Matthies and Matthies, 2018). A recommendation for practice would be to add these features to spaces, even if small, as they can increase use, attractiveness, nature connection and wellbeing (Schroeder, 1982; Nordh et al., 2009; Nordh and Østby, 2013; Wang et al., 2019).

When exploring other enabling features, open spaces were scored high for safety and visiting again. This is supported by previous research where preference is high for neater features with intermediate to high maintenance or open spaces (low density vegetation)(Bjerke et al., 2006; Jorgensen and Anthopoulou, 2007; Hofmann et al., 2012; Qiu et al., 2013; Weber et al., 2014; Lindemann-Matthies and Matthies, 2018). Therefore, an additional recommendation for practice would be to have appropriate lighting in spaces to help with seasonal use of the areas. Organised activities or park rangers have also been effective in increasing perceived safety (Jorgensen and Anthopoulou, 2007; Floyd et al., 2011; Baran et al., 2014; Hillier et al., 2016). Participants said they felt safer when there were more park users present. Specific features such as signs and cafes can facilitate greenspace satisfaction and perceived safety (Turkseven Dogrusoy and Zengel, 2017).

Local historical elements or art installations were appreciated, and participants wanted more context behind particular features such as an old Victorian bridge, a mill, and sundial or memorial statutes in the greenspace. A recommendation for practice would be to highlight these features, perhaps through a citywide trial or signs within greenspaces to offer further detail on the local context of the greenspace. Highlighting and maintaining these local cultural features can also act as a ‘cue to care’, promoting satisfaction and safety and deterring antisocial behaviour (Nassauer, 1995). Greenspace design should take into account the cityscape and social environment of that city. For example, Fischer et al. (2018a) found that within cities people prefer similar park settings, but between cities, it varies greatly.

Wellbeing

Wellbeing had a moderate positive correlation with attractiveness, perhaps as specific features such as flowers and formal planting that were highlighted by participants as attractive and good for their wellbeing were only very small parts of the greenspaces and participants requested more. Although participants associated greenness with wellbeing, the literature also highlights how colour can play a role in wellbeing and there was a distinct lack of other colours in these spaces due to the dominance of grass fields. Peak restorative value can be found when 'background green planting' is present, offering restorative benefits beyond attractive flowers that are temporary during the flowering season (Hoyle et al., 2017).

Here, I did not find a significant correlation between wellbeing and biodiversity, which differs from previous research (Fuller et al., 2007; Nordh et al., 2009; Dallimer et al., 2012; Carrus et al., 2015; Hoyle et al., 2017; Southon et al., 2018). For example, previous research found that when people perceive areas as biodiverse, they feel more satisfied with the area and more connected to nature and specific natural features such as trees, water and flowers increased the wellbeing benefits from the greenspace (Southon et al., 2018; Wang et al., 2019). However, one study found that planting attractiveness had a greater impact on restorativeness compared to perceived biodiversity (Lindemann-Matthies et al., 2010). Hoyle et al. (2017) also found that aesthetic appreciation was associated with restorativeness. Therefore, wellbeing could be driven by other dimensions such as attractiveness rather than biodiversity or perceived biodiversity. Safety or external influences such as the social environment may also drive wellbeing perceptions (Lo and Jim, 2010; Cronin-de-Chavez et al., 2019; Mears, Brindley, Maheswaran, et al., 2019). Issues present within the greenspace and in the local vicinity of the greenspace may affect the restorativeness of a greenspace. For example, Dallimer et al. (2012) found a negative association between litter in greenspace and wellbeing. Indeed, some of the participants in this study felt sad or had negative reflections after the walks they noticed litter, damage or deterioration of the greenspace. Greenspaces in this study were similar in quality but further research could explore the impact of quality on features, would more natural features in a high-quality greenspace be perceived as safer than the same feature in a low-quality greenspace? Would increasing the naturalness and biodiversity of features in a small low-quality greenspace increase attractiveness, satisfaction and wellbeing?

How does walking through greenspaces and noticing nature impact perceptions and wellbeing?

Overall, when using quantitative data, having a walk in the greenspace significantly improved wellbeing but did not impact nature connectedness, satisfaction, or perceived biodiversity. To the author's knowledge, this is the first study to measure before and after changes in perceived biodiversity. However, this study complements previous literature that has found positive wellbeing changes when participants were asked to notice the nature around them (compared to control groups)(Richardson and Sheffield, 2017; Bakolis et al., 2018; Dobson et al., 2021; McEwan et al., 2021). When using the qualitative data, it showed that the walk had a positive effect on some participants. After the walk, participants were open to using parts of the greenspace they had not used before or using the greenspace more often. They also mentioned using the spaces in new ways like for exercise or play. Participants expressed that they wanted to take more time to notice or hear nature in the greenspace in future visits. This shows that the walk as an intervention may influence how participants want to use a greenspace, particularly by showing them more natural areas of a greenspace they may not use already. However, a follow-up survey would test if these intentions translated into actions. It is difficult to explore the impact of a walk with quantitative survey methods so utilising wearable technology that can track heart rate, stress or blood pressure in real time could offer further insights into the features and mechanisms for promoting wellbeing in urban greenspaces. However, quantitative data alone is unlikely to capture the full range of perspectives from participants. Therefore, I would recommend using mixed methods in future studies that explore how people benefit from urban greenspaces.

Previous studies have demonstrated a relationship between species richness or perceived species richness and wellbeing (Fuller et al., 2007; Nordh et al., 2009; Dallimer et al., 2012; Carrus et al., 2015; Hoyle et al., 2017; Southon et al., 2018). I explored whether the guided walk, which asked participants to be mindful of nature, had an impact on their perceptions of the greenspace. The participants overestimated the number of species in the greenspace, which aligns with previous research that found that when biodiversity was low, respondents tended to overestimate (and underestimate when higher levels of biodiversity were present)(Lindemann-Matthies and Bose, 2008; Lindemann-Matthies et al., 2010). This supports previous findings where respondent's accuracy in predicting biodiversity was low (Lindemann-Matthies and Bose, 2008; Lindemann-Matthies et al., 2010; Leslie et al., 2010; Dallimer et al., 2012; Southon et al., 2018). Low biodiversity knowledge of respondents may also contribute to inaccurate perceived biodiversity. For, example, (Hoyle et al., 2017) found that those without university education perceived the highest amount of biodiversity, but Qiu et al., (2013) found that experts and laypeople had a similar ability to identify species richness. There is growing evidence of limited ecological knowledge in the developed world (Bebbington, 2005; Pilgrim et al., 2008). Increasing public engagement with nature may help increase ecological knowledge (Lindemann-Matthies, 2006; Coldwell and Evans, 2017) and increase perceived biodiversity accuracy, which in turn could impact the restorativeness of a greenspace (Dallimer et al., 2012; Southon et al., 2018; Wang et al., 2019). When exploring wellbeing received from natural features further, Richardson et al., (2021) found that only nature connectedness and engaging in simple nature activities had a significant impact on wellbeing, suggesting that only direct contact with nature increased wellbeing. Therefore, activities to increase nature connection and knowledge may be key to increasing the wellbeing benefits of urban greenspaces and without them the benefits received are limited. However, further research is needed into the impact of these activities over time – is novelty and learning something new part of the mechanism or does consistent participation in nature activities even when participants maintain the same level of knowledge offer benefits? Do these activities have a short-term impact on wellbeing or does regular participation sustain wellbeing benefits? I show that out of participants that have used the greenspace at least once before, some indicated they would use the park differently (particularly in relation to nature) after being show different areas and features. This result implies even if someone is familiar with a greenspace they may gain further benefits from additional knowledge or new uses.

I show that quantitatively there is no significant change between the number of perceived species before and after the walk. In general, perceived richness was overestimated and after the walk participants noted fewer perceived species for birds and butterflies, particularly as not many were observed during the walks. Further research could explore how observing birds and butterflies in a greenspace could influence wellbeing. The number of perceived plant species was higher after the walk but not significantly so. A participant's perceived plant species richness had a significant weak correlation with observed plant species richness, indicating that the walk may have influenced their perceptions. This complements previous literature that people are better at identifying and perceiving plants and contrasts a study that found identification of birds was more accurate (Fuller et al., 2007; Dallimer et al., 2012). What is emerging is that vegetation composition and structure have a disproportionate impact on the perceptions of greenspaces across multiple dimensions of safety, attractiveness, wellbeing and nature connection. Previous research has shown that the naturalness of the greenspace (particularly herbaceous planting) increased the perceived plant and invertebrate richness and when the evenness of species was lower so was the perceived species richness (Lindemann-Matthies et al., 2010; Hoyle et al., 2017; Southon et al., 2018). Indeed a lack of vegetation or sparse vegetation has been found to have a low preference and low perceived safety in previous studies (Hands and Brown, 2002; Nordh and Østby, 2013; Weber et al., 2014; Harris et al., 2018). Whereas, Fischer et al., 2018a, found that people have a preference for high plant species richness in urban greenspaces (n=3716) and was consistent across socio-cultural groups across five European cities. Weber et al. 2014found that although trees are important features for perceptions of greenspaces city-dwellers also perceive managed and wild green components such as vegetation beyond just trees. Due to the complexity and length of the waypoint survey, I did not ask participants the number of species they perceived to be in that waypoint. However, future research could explore perceived species richness at a feature (waypoint level) and how characteristics of those features such as colour, naturalness, density and height of vegetation, and species evenness impact the perceptions across multiple dimensions of attractiveness, safety, nature connection and wellbeing.

Perceptions of greenspaces and wellbeing benefits from greenspace can differ across socio-economic and demographic groups such as income, gender, migrant background, living environment, education, ecological knowledge and profession (Bjerke et al., 2006; Maas et al., 2009; Hofmann et al., 2012; Dadvand, Wright, et al., 2014; McEachan et al., 2016; Rigolon, 2016; Turkseven Dogrusoy and Zengel, 2017; Hoyle et al., 2017; Fischer et al., 2018b; Southon et al., 2018; Ferguson et al., 2018; Fischer et al., 2018a; Corley et al., 2018; Ojala et al., 2019; Mears, Brindley, Maheswaran, et al., 2019; Fischer et al., 2020). Greenspaces in deprived areas or more racially diverse areas may have lower access, safety aesthetic value and maintenance (Rigolon, 2016; Corley et al., 2018). Hoyle (2020) show that ethnic minorities are less likely to perceive wilder nature as pleasant. Van den Berg and Koole (2006) found that study, place of residence, age, socio-economic status, farming background, preference for green political parties, and recreational motives were found to be systematically related to relative preferences for wild versus managed nature scenes. I recommend that these socio-demographic elements should be explored alongside the multiple dimensions of safety, attractiveness, nature connection, wellbeing and biodiversity, many studies only focus on one of a few of these dimensions. A multi-dimensional approach will help to identify consensus and win-win features or ways to mitigate negative perceptions of high biodiverse or natural features. Finding consensus or areas of low use can support decisions about the management of different areas of the greenspace. For example, if areas within a greenspace are used less and more natural, a land-sparing approach could be applied to maximise biodiversity in these areas. I would recommend on-site explanations of the biodiversity benefits of features that are perceived as messy or unsafe to reduce concerns about safety or attractiveness. Alternatively, areas of low use and low biodiversity could have targeted features or interventions to encourage use (such as organised events on open grass fields).

5.6 Conclusion

Here, I explored a gap in the current literature on greenspace use and wellbeing by taking a multidimensional approach to understand greenspace user perceptions of specific park features, with special reference to biodiversity. There are a range of perspectives on biodiversity in greenspace features. Biodiversity plays a role in these perspectives as an enabling feature bringing users to that area or offering wellbeing benefits, but there can also be trade-offs associated with attractiveness and safety. I make specific recommendations to address these. Win-win features (formal planting, grass, pitch, scrub, wood and wood edge) scored well across the dimensions of attractiveness, safety, biodiversity and wellbeing and can facilitate park use and nature connection opportunities. However, quality and management of these features are key to balancing the trade-offs between biodiversity and attractiveness or safety. Educational signs are needed to explain why particular interventions such as unmown areas are intentional and not signs of neglect. These interventions can potentially save money for local governments responsible for managing these public greenspaces. I show that a walk in the park where participants focus on wildlife and natural features can influence perceptions of greenspace features and wellbeing. However, it is difficult to capture the full range of impacts with quantitative methods. Qualitative data showed that participants had positive feelings towards nature in greenspace and wanted to know more or notice it more after the walk, despite nature connectedness and satisfaction not significantly changing. Therefore, future research should explore the perceptions of greenspace users for particular features but also the impact of encouraging greenspace users to take notice of these features during their use of the greenspace. This has implications for increasing nature connection, satisfaction and wellbeing, if greenspace user perceptions and or wellbeing can be influenced by guided walks in their greenspace or signs with information about the features in the greenspace these could be included in future management if further evince emerges through future study. Is the satisfaction, nature connection and wellbeing of some greenspace users limited due to a lack of knowledge about the greenspace features and could the benefits they receive from the greenspace be increased through these simple interventions? I show that this mechanism potentially exists but requires further study, especially as quantitative methods used in this study did not show a change contrasting the qualitative data from participants. It is clear that biodiversity is valued and greenspace users are open to learning more about biodiversity features in their local greenspace but care should be taken to address their concerns around safety and attractiveness.

5.7 Supplementary Material

Pre-walk survey questions

Note pictures used in the nature quiz are creative commons with no attribution required.

1. What best describes your ethnic group or background? [South Asian, Eastern European, Black, White; English/Welsh/Scottish/Northern Irish/British, other ethnic or mixed/multiple ethnic backgrounds]
2. Are you a member of an environmental organisation? [Yes/No]
3. Have you ever used this green space before? [Yes/No]
4. Please score each statement from 1-5 (1 being strongly disagree, 5 being strongly agree)
    - It is easy to find my way into this park:
    - It is easy to find my way around this park
    - I believe that the quality of my local park can impact my health
5. Have you used this park for any of the following activities? Select all of those which apply to you. [walking, walking a dog, playing with children, picnicking, running, informal games/sports, wildlife watching, appreciating scenery from your car, off-road biking, off-road motorcycling, relaxation, other] source (Natural England, 2009)
6. What 3 words would you use to describe this park? [Free text]
7. How satisfied are you with this park? (1 extremely dissatisfied, 5 being extremely satisfied)
8. Why do you feel this way about this park? What do you like or dislike about the place? [Free text]
9. How safe would you feel in this park in the day? (1 being extremely unsafe, 5 being extremely safe)
10. How safe would you feel in this park in the evening? (1 being extremely unsafe, 5 being extremely safe)
11. Please indicate how concerned you are about the following issues in your local area (1 being extremely concerned, 5 extremely agree)
    - Local air quality

- Crime and antisocial behaviour in local parks and greenspaces

12. How many different types of birds do you think there are in this park? [Free text]

13. How many different types of butterflies do you think there are in this park? [Free text]

14. How many different types of plants do you think there are in this park? [Free text]

15. Ecological knowledge questions, see Figure 5.7 below

16. Thinking of this greenspace, please score each statement from 1-5:

    - There is much to explore and discover here
    - This place is a refuge from unwanted distractions
    - I would be able to rest and recover my ability to focus in this environment]
    - I like this environment
    - I feel safe in this park

Please score each statement from 1-5:

- My ideal vacation spot would be a remote, wilderness area
- I always think about how my actions affect the environment
- My connection to nature and the environment is important to me
- I take notice of wildlife wherever I am.]
- My relationship to nature is an important part of who I am.]
- I feel very connected to all living things and the earth]

Figure 5.7. Questions used in the nature quiz to explore participants' ecological knowledge. The questions are designed to increase in difficulty within each taxon.

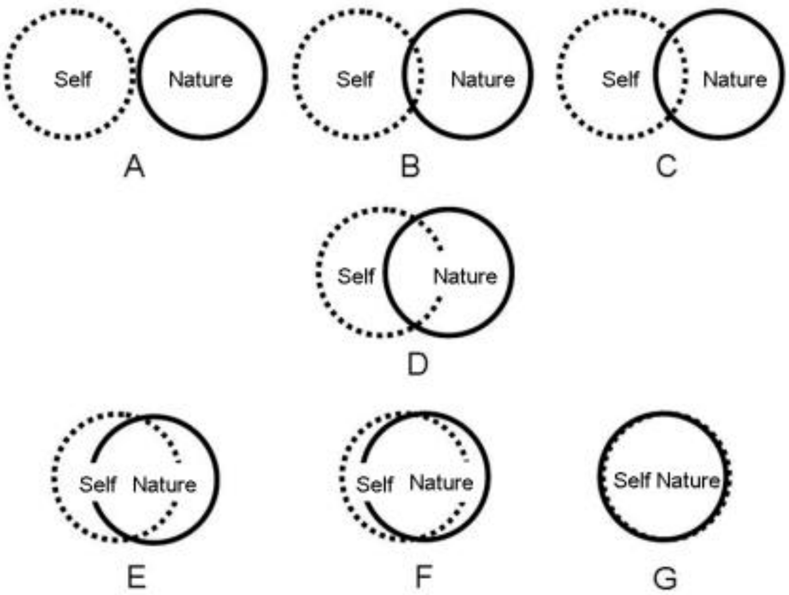
Waypoint Survey questions:

1. Please score each statement from 1-5 (1 being strongly disagree, 5 being strongly agree) based on your current location within the park:

    - I can easily access this area
    - I am far away from urban structures (e.g. roads or buildings)
    - The air here is fresh
    - I could come here to escape from urban noise
    - I can hear bird song
    - I can hear leaves rustling
    - I can hear traffic
    - There is no litter here
    - This area is in good environmental condition
    - I notice a lack of nature around me
    - There is no opportunity for nature here]
    - I consider this area to be wild
    - I would like to come to this area again after this walk
    - There is much to explore and discover here
    - This place is a refuge from unwanted distractions
    - I would be able to rest and recover my ability to focus in this environment
    - I like this environment
    - This area is attractive
    - There is opportunity for activity here (e.g. community, sports, culture)
    - This area is neat/well-maintained
    - This area is highly modified
    - This is a safe place for children to play

- I would describe the ground as uneven
- I feel trapped
- I feel trapped
- I feel relaxed
- I feel comfortable
- I feel lost
- If alone, I would feel safe in the area in the day
- If alone, I would feel safe in this area in the evening
- In a group, I would feel safe in this area in the day]
- In a group, I would feel safe in this area in the evening]

2. Can you smell the following features? Yes or No
    - Grass
    - Flowers
    - Soil
    - Water
    - Cars
3. What particular features led you to score this area high or low when thinking about safety? [Free text]
4. Thinking back to 'I consider this area to be wild', what particular features in this area led you to score this statement high or low? [Free text]
5. How interconnected with nature are you right now? Please circle a diagram (A-G) that best describes your relationship with nature at this point in time? Source:(Schultz, 2001)



6. Why did you choose to take this photo? Are there any particular features in your photo that you like or dislike? [Free text]

Post-walk survey

Participant ID

Park

1. How many different types of birds do you think there are in this park? [Free text]
2. How many different types of butterflies do you think there are in this park? [Free text]
3. How many different types of plants do you think there are in this park? [Free text]
4. Did you notice any features along the walk that would attract you to use that area of the park? If yes, what? [Free text]
5. Would built features (e.g. benches or footpaths) encourage you to access the wilder areas? If yes, what features? [Free text]
6. Having experienced different environments on today's walk please score each statement from 1-5
    - Air quality is important to me
    - Reduced urban noise is important to me
7. What 3 words would you use to describe this park? [Free text]
8. How satisfied are you with this park? (1 extremely dissatisfied, 5 being extremely satisfied)
9. Why do you feel this way about this park? What do you like or dislike about the place?
10. How safe do you feel in this park? (1 being extremely unsafe, 5 being extremely safe)
11. I will use this park differently now that I have been on this walk. If so, how?
12. Thinking of this greenspace, please score each statement from 1-5:
    - There is much to explore and discover here
    - This place is a refuge from unwanted distractions
    - I would be able to rest and recover my ability to focus in this environment]
    - I like this environment
    - I feel safe in this park

13. Please score each statement from 1-5:

    - My ideal vacation spot would be a remote, wilderness area
    - I always think about how my actions affect the environment
    - My connection to nature and the environment is important to me
    - I take notice of wildlife wherever I am.]
    - My relationship to nature is an important part of who I am.]
    - I feel very connected to all living things and the earth]

14. How do you feel about the journey of today's walk? Have you been affected in any way? [Free text]
15. Will you now do something differently in your own life to help wildlife (e.g. change the way you manage your garden)? If yes, what will you do? [Free text]

Table 5.10. The survey questions associated with each research question.

Basic information about participants	Pre-walk survey	What best describes your ethnic group or background? [South Asian, Eastern European, Black, White; English/Welsh/Scottish/Northern Irish/British, other ethnic or mixed/multiple ethnic backgrounds] Are you a member of an environmental organisation? [Yes/No] Ecological knowledge questions, see Figure 5.7
	Waypoint survey	NA
	Post-walk survey	NA
Basic information about greenspace	Pre-walk survey	Have you ever used this green space before? [Yes/No] Please score each statement from 1-5 (1 being strongly disagree, 5 being strongly agree) • It is easy to find my way into this park: • It is easy to find my way around this park • I believe that the quality of my local park can impact my health Have you used this park for any of the following activities? Select all of those which apply to you. [walking, walking a dog, playing with children, picnicking, running, informal games/sports, wildlife watching, appreciating scenery from your car, off-road biking, off-road motorcycling, relaxation, other] source (Natural England, 2009) What 3 words would you use to describe this park? [Free text] How satisfied are you with this park? (1 extremely dissatisfied, 5 being extremely satisfied) Why do you feel this way about this park? What do you like or dislike about the place? [Free text] Please indicate how concerned you are about the following issues in your local area (1 being extremely concerned, 5 extremely agree) • Local air quality • Crime and antisocial behaviour in local parks and greenspaces
	Waypoint survey	NA
	Post-walk survey	Did you notice any features along the walk that would attract you to use that area of the park? If yes, what? [Free text] Would built features (e.g. benches or footpaths) encourage you to access the wilder areas? If yes, what features? [Free text] Having experienced different environments on today's walk please score each statement from 1-5 • Air quality is important to me • Reduced urban noise is important to me

How do people perceive different greenspace features with reference to the following dimensions of experience: attractiveness, safety, wellbeing, nature connection and biodiversity? Are there features that score high across all the dimensions and offer win-win opportunities?	Pre-walk survey	How safe would you feel in this park in the day? (1 being extremely unsafe, 5 being extremely safe) How safe would you feel in this park in the evening? (1 being extremely unsafe, 5 being extremely safe) Thinking of this greenspace, please score each statement from 1-5: • There is much to explore and discover here • This place is a refuge from unwanted distractions • I would be able to rest and recover my ability to focus in this environment] • I like this environment • I feel safe in this park Please score each statement from 1-5: • My ideal vacation spot would be a remote, wilderness area • I always think about how my actions affect the environment • My connection to nature and the environment is important to me • I take notice of wildlife wherever I am.] • My relationship to nature is an important part of who I am.] • I feel very connected to all living things and the earth]
	Waypoint survey	Please score each statement from 1-5 (1 being strongly disagree, 5 being strongly agree) based on your current location within the park: • I can easily access this area • I am far away from urban structures (e.g. roads or buildings) • The air here is fresh • I could come here to escape from urban noise • I can hear bird song • I can hear leaves rustling • I can hear traffic • There is no litter here • This area is in good environmental condition • I notice a lack of nature around me • There is no opportunity for nature here] • I consider this area to be wild • I would like to come to this area again after this walk • There is much to explore and discover here • This place is a refuge from unwanted distractions • I would be able to rest and recover my ability to focus in this environment • I like this environment • This area is attractive

<table>
<tr><td></td><td></td><td>There is opportunity for activity here (e.g. community, sports, culture)
This area is neat/well-maintained
This area is highly modified
This is a safe place for children to play
I would describe the ground as uneven
I feel trapped
I feel trapped
I feel relaxed
I feel comfortable
I feel lost
If alone, I would feel safe in the area in the day
If alone, I would feel safe in this area in the evening
In a group, I would feel safe in this area in the day]
In a group, I would feel safe in this area in the evening]
Can you smell the following features? Yes or No
Grass
Flowers
Soil
Water
Cars
What particular features led you to score this area high or low when thinking about safety? [Free text]

Thinking back to 'I consider this area to be wild', what particular features in this area led you to score this statement high or low? [Free text]

How interconnected with nature are you right now? Please circle a diagram (A-G) that best describes your relationship with nature at this point in time? Source:(Schultz, 2001)

Why did you choose to take this photo? Are there any particular features in your photo that you like or dislike? [Free text]</td></tr>
<tr><td></td><td>Post-walk survey</td><td>NA</td></tr>
<tr><td rowspan="3">How does actively thinking about greenspace features while walking through a greenspace influence perceptions of that greenspace?</td><td>Pre-walk survey</td><td>How many different types of birds do you think there are in this park? [Free text]

How many different types of butterflies do you think there are in this park? [Free text]

How many different types of plants do you think there are in this park? [Free text]</td></tr>
<tr><td>Waypoint survey</td><td>NA</td></tr>
<tr><td>Post-walk survey</td><td>How many different types of birds do you think there are in this park? [Free text]</td></tr>
</table>

		How many different types of butterflies do you think there are in this park? [Free text] How many different types of plants do you think there are in this park? [Free text] What 3 words would you use to describe this park? [Free text] How satisfied are you with this park? (1 extremely dissatisfied, 5 being extremely satisfied) Why do you feel this way about this park? What do you like or dislike about the place? How safe do you feel in this park? (1 being extremely unsafe, 5 being extremely safe) I will use this park differently now that I have been on this walk. If so, how? Thinking of this greenspace, please score each statement from 1-5: • There is much to explore and discover here • This place is a refuge from unwanted distractions • I would be able to rest and recover my ability to focus in this environment] • I like this environment • I feel safe in this park Please score each statement from 1-5: • My ideal vacation spot would be a remote, wilderness area • I always think about how my actions affect the environment • My connection to nature and the environment is important to me • I take notice of wildlife wherever I am.] • My relationship to nature is an important part of who I am.] • I feel very connected to all living things and the earth] How do you feel about the journey of today's walk? Have you been affected in any way? [Free text] Will you now do something differently in your own life to help wildlife (e.g. change the way you manage your garden)? If yes, what will you do? [Free text]

6 General Discussion

In this thesis, I demonstrate the strength of an interdisciplinary, mixed-methods and place-based approach for unpacking prevailing assumptions in greenspace research and offer novel insights and further understanding of the relationship between greenspace biodiversity and health and wellbeing. Understanding the various dimensions of green is important for unpacking the mechanisms for health and wellbeing benefits from greenspaces. I also include smaller informal greenspaces, which are often overlooked but are important features of the urban environment and also offer health and wellbeing benefits. I address some prevailing assumptions on the definition of greenspace, methods to measure 'green' in greenspace, access and exposure to greenspace and how or why people use greenspace features. I identify win-win features that could provide benefits for biodiversity and people, particularly younger years which are often neglected in greenspace studies and provision. I explore some prevailing assumptions present in greenspace research below using data from this study and offer specific recommendations for addressing assumptions in greenspace research. I provide synthesis across thesis chapters and explore overarching themes that emerge from multiple chapters.

This thesis was designed around the Better Start Bradford Better Place Project that aimed to co-design the greenspace interventions with community to improve health and wellbeing and promote biodiversity and nature connection (Better Start Bradford, 2023). As a result, alongside addressing some of the prevailing greenspace assumptions, I gathered useful baseline data and established a controlled, before-and-after design to provide evidence to inform the co-design of greenspaces with multiple stakeholders to promote benefits for biodiversity and people. Due to the coronavirus pandemic, the analysis for this thesis was completed before many interventions were implemented and, at the time of writing, the evaluation of these interventions is still outstanding. As the World Health Organisation and the European Landscape Convention recommend co-design for all greenspaces (The Council of Europe, 2004; World Health Organization, 2017). As part of this co-design process, it was key for evidence from my work (these thesis chapters) on biodiversity, greenspace use and community perceptions to be integrated into the co-design process of greenspaces in the study area. Therefore, I provide insights and examples from my data for greenspace intervention design. I also offer insights into exploring links between health and wellbeing outcomes and biodiversity at scale (across multiple neighbourhoods), which is a novel aspect of this study. As my reflections are not from repeatable or formalised data collection methods, they are included in this general discussion chapter to inform other greenspace studies or projects and not presented as a data chapter.

6.1 Addressing assumptions in greenspace research

Chapter 2: Defining and evaluating greenspaces

In the first data chapter, I explored the literature on definitions of greenspaces, which are many and varied due to the multidisciplinary nature of the work carried out. However, I did not offer a single definition of greenspace as this will vary from study to study but instead provide a standardized method for describing greenspaces to aid in collating evidence from projects in similar systems. Stakeholders working on the same greenspace project with different backgrounds ranked a list of possible greenspace descriptors. Areas of consensus were highlighted, producing a list of descriptors for standard reporting across greenspace projects. The method was repeated for a list of metrics used in greenspace studies from multiple disciplines (planning, ecology, social sciences and public health). There was some agreement across multiple stakeholders to report the type of greenspace, user quality of the space, size of greenspace and blue space (in area unit), ownership of the space, number of people with access to the greenspace, and the number and size of habitats in the greenspace in every greenspace project. However, I identified gaps in descriptors deemed important for multiple stakeholders that were not being used by the stakeholders in their project work (such as the economic and social value of the greenspace). I place these findings in the context of the wider literature to show where there is consensus between the literature and participating stakeholders. I also offer additional measures for future greenspace studies that were not included in the list by the stakeholders but have demonstrated value in the literature.

The outcome is not a prescribed list of metrics for studies but to offer some direction for future work by highlighting metrics that are valued and used by multiple stakeholders. It aims to provide a suite of metrics to raise awareness of what has been done or could be used in greenspace projects and which metrics could appeal to multiple stakeholders. This is valuable for urban greenspace project design and evaluation as the study of these spaces is usually interdisciplinary in nature and focuses on managing public goods for public benefits. Collecting and sharing data that is useful across multiple stakeholders from the same greenspace project can be particularly helpful in the current climate where there are limited resources for local governments to manage greenspaces.

I built a list of descriptors of urban greenspaces which I recommend all greenspace projects use. This list was created through consensus from a range of stakeholders including academics, practitioners, delivery partners, community workers and local government and aims to be accessible to use for these stakeholders. Combining stakeholder preference and literature the following descriptors are recommended as a baseline for all future greenspace studies: define and give example of greenspace, physical characteristics (such as size, habitats and amenities), ownership, and management, access (number of people living in a given distance), species richness and abundance and the spatial context of the greenspace in relation to other greenspace at a relevant scale (such as local or regional).

Based on stakeholders feedback and literature review I recommend that the following metrics should be explored in future greenspace studies: activities and events organised in greenspaces, number of visitors to greenspace, types, frequency and intensity of greenspace use, environmental value of green infrastructure, social value of green infrastructure, the amount of space to meet, socialise or exercise in the greenspace, the socio-cultural context (such as the crime, community-connectedness or health inequalities in the surrounding area) and individual factors (such as connection to nature or environmental awareness).

I would also recommend that future studies on greenspace use the one-word compound of greenspace to make it easier to capture relevant literature in future literature searches, systematic reviews and meta-analyses. I support Rojas-Rueda et al. (2021) and also recommend that studies exploring greenspace and health should always include well-cited methods for measuring greenspace exposure and an internationally agreed definition of a health outcome as a baseline (such as those defined in the International Classification of Disease code).

Chapter 3: Measuring green exposure and access and links to health and wellbeing

Much of the literature on urban greenspace and health uses a buffer method to measure the surrounding greenness (using Normalized Difference Vegetation Index, NDVI) at set distances from an individual's home (Jarvis et al., 2020). Often smaller informal greenspaces (particularly street-level) are excluded from these methods. This method also assumes a different pattern of exposure than the exposure experienced by travelling through the built environment, which includes smaller informal greenspaces (Rupprecht and Byrne, 2014; Christensen et al., 2021). It also assumes these greenspaces are of equal quality, which may not be the reality and it is clear that low-quality greenspace can have negative impacts on health and wellbeing (Lee et al., 2015; Cronin-de-Chavez et al., 2019; Birch et al., 2020; Knobel et al., 2021).

Therefore, in Chapter 3 I compared methods of measuring greenspace using traditional buffer methods to network-based methods that explore exposure as an individual moves through the built environment. I go further by including smaller informal greenspaces in this analysis. I found that there were no relationships between the buffer and network methods for measuring greenspace exposure; they measure different exposures. Different methods were better suited for different health and wellbeing outcomes, 16 of the 23 models where a greenspace term was a statistically significant predictor of a health outcome were network-based measures and the remaining 7 were buffer-based measures. Network based methods may offer a more realistic measure of how people move through the built environment and their exposure to greenspace any associated benefits.

Future studies should assess which method is best suited to their research and not apply buffer methods by default or without evidence or clear justification for applying the method. Studies could use both buffer and network methods for exploring the relationship between greenspaces and health outcomes, dependent upon the outcome being studied or the mechanisms of greenspace action being tested. Studies could also combine network and buffer methods with self-defined areas of activity or use mobile or wearable technology to record an individual's journeys and greenspace use.

Existing research often uses satellite-derived measures such as Normalized Difference Vegetation Index (NDVI) or land cover. However, the scale of these measures (30-100 m) may miss important street-level differences in green exposure. Although this method distinguishes between levels of greenness there is an underlying assumption that all greenspace is of the same quality or that the satellite measurements of greenness correlate with the environmental benefits of greenspaces. However, quality can influence the use of a greenspace (Lee et al., 2015; Cronin-de-Chavez et al., 2019; Birch et al., 2020). Therefore, I measured the biodiversity, user quality and street-type (trees only, trees and grass, grass only or no green present).

I found that some alternative measures of green have relationships with health outcomes. For example, babies were less likely to have an unhealthy-low birthweight with higher species richness within 300 m (buffer). However, for adults, higher species richness 300 m from their home was associated with lower wellbeing (buffer) and more severe depression (network). The street-level green measure had the highest explanatory power for some health outcomes too. For example, healthy birthweight was less likely but unhealthy-high birthweight was more likely for those with a greater number of grey streets (no green infrastructure) in their surrounding area. Gestational diabetes was more likely with tree-only streets within the surrounding area. These results show that alternative measures of green could be more relevant for research questions exploring lived exposure to greenspace and exposure to smaller informal greenspaces. My results move the existing literature forward by highlighting a straightforward method to capture street-level green and that the absence of green on a street-level has a relationship with some health outcomes.

Alternative measures of surrounding greenness may offer a better understanding of the relationship between urban greenspaces and health or wellbeing outcomes beyond NDVI measure of 'greenness'. This is the first study to my knowledge to explore biodiversity and health on a large scale (samples of 2644 and 5240) and directly comparing that to NDVI methods. I would recommend that future studies include species richness (the measure of biodiversity) and street-level green in their analysis. I recommend using the simple street-green typology I created (grey (no green), grass only, tree only, tree and grass) as a starting point for exploring a more realistic way of quantifying surrounding green and exposure.

Traditional methods of measuring green exposure often involve NDVI or greenspace area in a buffer area as the data is more readily available and the buffer analysis is straightforward. However, this study found that NDVI buffer measures did not always have the most explanatory power, using other measures of green could explain more variation in the health and wellbeing outcomes. However, collecting the data for the alternative measures of green is more difficult so I compared the traditional NDVI buffer methods to the alternative measures of green. I found similar levels of explanatory power when I compared the traditional measures (buffer-based NDVI) to the alternative measures and method (network). The same results were found when comparing greenspace area (buffer method) to the alternative measures and method (network). Therefore, NDVI and greenspace area using the buffer methods can act as a good proxy for other more sophisticated measures of green. However, this thesis goes beyond the existing literature that uses NDVI as a default with little evidence as to why it is considered a superior measure of green exposure. Here I evidence why and some cases when NDVI can be used as a suitable proxy for more nuanced measures of green but in other contexts alternative measures will offer more in-depth insight.

A recommendation for future studies would be that NDVI and greenspace area measures of surrounding green applied with buffer methods can be used as a proxy for more detailed measures of surrounding green. However, these methods should not be used by default in future research. Alternative green measures and network-based methods could be more appropriate for tracking changes in health and wellbeing outcomes in response to interventions that change quality of greenspaces (such as increasing species richness or user quality) or street-level green (such as tree planting). I agree with Rojas-Rueda et al. (2021) that NDVI is a good indicator of surrounding green and offers valuable insight for relationships with health and wellbeing and due to its global availability its use can help with collating, synthesising and meta-analysis of evidence from greenspace studies. Therefore, I recommend that NDVI is used as a standard but not at the expense of alternative measures, and that the justification for using it over other measures of green is made clear in each study. Using NDVI and alternative green measures will offer opportunities for greater understanding and better collation of evidence, which as demonstrated in Chapter 2, is hindered by the range of definitions and methods applied in this multi-disciplinary field. As NDVI is widely used already in the literature, I recommend using NDVI alongside alternative measures, because this continued use of NDVI in research will aid evidence synthesis and meta-analysis across studies (Rojas-Rueda et al., 2021).

Chapter 4: Diversity in the use of greenspace and impacts on associated health benefits

Literature using the traditional methods described above can assume that those living close to greenspaces, use those spaces in a similar way and that there are equal benefits across the community. But the literature shows that this may not always be true, especially as some community members may not feel able to use the spaces even if they live nearby (Lo and Jim, 2010; Mears, Brindley, Maheswaran, et al., 2019). Furthermore, greenspaces are often considered as a single unit with little attention given to the distinct and varied areas within a space. Greenspace users can use some areas and not others and have a range of activities that may span multiple areas of a greenspace (from playgrounds to picnic areas). There is a need to understand the impact of the characteristics of greenspaces (including different features, quality, and biodiversity) on health outcomes and how this relates to individuals in urban greenspaces (Kruize et al., 2020; Knobel et al., 2021). I used a mixed-methods approach to explore this relationship in Chapter 4 and base the below recommendations around combined data from both methods. Specific findings for urban greenspace design to encourage use and physical activity are explored in ‘6.3 Implications for greenspace design and management’ and not in the recommendations below.

First, I used a standardized method for observing the physical activity (or inactivity) of greenspace users across distinct areas of the greenspace. To explore any relationship with biodiversity I also recorded the biodiversity in each distinct area of the greenspace. I found that people use greenspace differently, particularly between age groups and genders. I found that playgrounds are the most used features in greenspaces and park users of all age groups. When looking at features with more biodiversity, features with trees (single trees or tree-lined paths) were popular. However, only a small number of greenspace visitors (mostly adult males) used densely vegetated and woodland areas. I found that the relationship between biodiversity and use or physical activity was unclear. However, there were significantly more sedentary observations in areas with higher species richness (particularly trees species richness), which may reflect the restorative properties of biodiversity (Dallimer et al., 2012; Lovell et al., 2014; Wood et al., 2018; Lovell et al., 2020; Marselle et al., 2021). To my knowledge, these findings linking biodiversity and physical activity levels are novel.

I wanted to understand the greenspace user perspective of the spaces and identify the barriers and enablers to using these distinct areas of the greenspaces. Therefore, I conducted guided walks where greenspace users could direct us around the greenspace and record feelings and take pictures of particular points of interest to them. I found that participants valued playgrounds but wanted to make more use of other areas of the greenspace. Natural features were highly valued when they were managed to be safe and attractive and facilitated natural play or relaxation. This chapter highlights the importance of co-design. Without consulting the stakeholders, the conclusions would have been to increase playgrounds, potentially at the expense of biodiversity or other areas of the park. However, with stakeholders involved in the process it was clear that having varied and distinct areas with a range of green (habitats and other biodiversity) and grey features (such as playgrounds and paths) was important to greenspace users.

I recommend that traditional methods of exploring relationships between urban greenspaces health and wellbeing based on buffer analysis should be supplemented by mixed-methods to observe greenspace behaviour and the underlying reason for this behaviour. By combining top-down satellite-based measures with observational and community participation data (such as photo voice) a clearer picture of who is using and therefore benefiting from the greenspace (and for physical activity the scale of those benefits). This will help address gaps and disparities in who benefits from urban greenspaces.

Observation methods are a good foundation for understanding the current use of a greenspace and tools like SOPARC can offer insight into age, ethnicity and activity levels of the greenspace users and which areas are used. However, in the absence of further data the conclusions may not be representative of the whole community (as it doesn't capture those that don't use the greenspace) or future aspirations for the greenspace. In Chapter 4, if only observational methods were used, there would be an assumption to increase playgrounds, which is valid and supported by participants, but this could come at the expense of other areas of the greenspace, and negatively impact biodiversity (which is not accounted for in the SOPARC methodology). However, in participatory methods, community members wanted more biodiversity and to use more biodiverse areas. Therefore, I demonstrate why it is key to use mixed-methods (observation and community participation) when exploring greenspace interventions for promoting use and the associated benefits of urban greenspaces.

Therefore, participatory methods should be used to collect additional information from community members that live near the greenspace, aiming to capture people who may not use the greenspace (or specific areas of the greenspace) and the reasons behind the patterns of use observed and aspirations for use.

This is the first study to my knowledge to explore biodiversity and health on a SOPARC target area level. This was to explore the patterns of use within a greenspace and in relation to specific features. Here, I demonstrate that biodiversity and specific features (such as woods or tree-lined paths) can play a role in how parts of a greenspace are used. This expands existing literature that often explores greenspace as a single unit neglecting the variation within.

I recommend that urban greenspace should be explored as a complex space with a mosaic of areas and uses within that space. Defining the mosaic can be achieved through applying standardized techniques such as the SOPARC tool to create target areas. I also recommend that future research on patterns of use (such as SOPARC) include species richness (the measure of biodiversity) measure for different areas of the greenspace (such as the SOPARC target areas level).

Chapter 5: How do perceptions of greenspace features impact use and wellbeing benefits?

Previous literature and data from Chapter 2 and Chapter 4 show that urban greenspaces have multiple requirements to support biodiversity and health and wellbeing but there are trade-offs around features that are good for biodiversity (such as woods and wood edge) and perceived safety or attractiveness (Schroeder, 1982; Schroeder and Anderson, 1984; Hands and Brown, 2002; Bjerke et al., 2006; Van den Berg and Koole, 2006; Nordh et al., 2009; Lindemann-Matthies et al., 2010; Nordh and Østby, 2013; Weber et al., 2014; McMahan et al., 2016; Hoyle et al., 2017; Harris et al., 2018; de Bell et al., 2018; Fischer et al., 2020; Hoyle et al., 2019; Wang et al., 2019; Mouratidis, 2019). These perceptions of these features can also impact wellbeing or use of the greenspace (Nordh et al., 2009; Nordh and Østby, 2013; Hoyle et al., 2017; Southon et al., 2018; Lindemann-Matthies and Matthies, 2018; Wang et al., 2019 and see Chapter 4). Previous research has explored some of these trade-offs but often only focus on a few such as biodiversity, attractiveness and wellbeing or biodiversity and safety. Therefore, in Chapter 5, I take a multidimensional approach and explore biodiversity, safety, attractiveness, nature connection and wellbeing in relation to different greenspace features. To capture realistic responses about perceptions of greenspace features I conducted in-situ surveys with participants on a guided walk with set waypoint for each feature. From these walks, it was clear that vegetation was a diving force for perceptions, particularly safety, attractiveness and wellbeing. Win-win features (formal planting, grass, pitch, scrub, wood and wood edge) scored well across the dimensions of attractiveness, safety, biodiversity and wellbeing and can facilitate park use and nature connection opportunities. Although there are still a range of ways people perceive different greenspace features, these win-win features may act as a foundation for consensus (if managed carefully) and may also offer cost-effective ways to manage some areas of urban greenspaces (O'Sullivan et al., 2017).

Based on these findings, to increase opportunities for wellbeing, nature connection, use and biodiversity, greenspace decision makers should explore implementing or maintaining the win-win features of formal planting, grass, pitch, scrub, wood and wood edge. These can offer benefits for people, wildlife and potentially be cost saving. However, this should be explored with local community members as this may vary across cultures.

The results from this study align with those from Chapter 4, as natural features (such as trees, woods, flowers, rocks, water and birds) were valued and if of a high quality are perceived as enabling features for use and nature connection. However, special care to manage these features is needed as participants shared that particular features such as scrub or wood with dense vegetation are perceived as unsafe. Interventions can include paths and organised activities, in turn any increased footfall can help these spaces feel safer. While participants requested educational resources such as signs about specific natural features that may appear messy (such as unmown grass and deadwood). Pervious literature has shown providing educational signs and public engagement around the biodiversity value of these features can shift negative messy perceptions to positive perceptions. Therefore, to address perceptions of natural features as being unsafe, I recommend that signs are put in place alongside these features to address negative perceptions and provide learning opportunities requested by the participants.

Other park features that were highlighted in Chapter 4 such as playgrounds, paths and open spaces were also recognised as enabling use and wellbeing. The participants valued having a variety of greenspace features and expressed the benefits of a variety for people's health and wellbeing and wildlife, which is supported by previous research (Meyer-Grandbastien et al., 2020). Participants also highlighted in the responses and pictures a number of locally significant features such as a Cotton Mill in the distance, war memorials and art installations. Participants also highlighted the attractiveness, wellbeing and biodiversity benefits of flowers and requested more (in either wildflower areas or formal planting like flowerbeds). Indeed, areas with formal planting were highlighted as the feature most would visit again. Therefore, to facilitate positive perceptions and wellbeing, greenspaces should include a range of features that are natural (tree avenues) and less natural (like playgrounds). For example, flowers were another key features for participants. However, I recommend implementing a mixture of greenery and flowers as these are recognised as beneficial for people and nature by greenspace users, while flowers alone may only have a temporary impact on attractiveness, use and wellbeing (as found by Hoyle et al. 2017). A mosaic approach (including features such as meadows with mown paths, formal planting, open fields and low density undergrowth in urban woodland) could be applied to provide a variety in greenspace features that support biodiversity while addressing safety concerns and offer 'cues to care' (Schroeder and Anderson, 1984; Jorgensen et al., 2002; Jansson et al., 2013; Fischer et al., 2020).

A further recommendation would be for greenspace decision makers to protect, restore and provide educational resources around the local history and cultural context of the greenspace as this may encourage greater satisfaction and use of the greenspace and areas within.

As a walk in greenspaces (even as short as 15 minutes) has been shown to improve wellbeing, I recorded the wellbeing before-and-after the walk and reflections about the greenspace after the walk (Shanahan et al., 2016; Cox et al., 2018; White et al., 2019; Roberts et al., 2019; Dobson et al., 2021). I also recorded if satisfaction, nature connection and perceived species richness changed but there was no significant change in these perceptions quantitatively. However, the walk significantly increased participant wellbeing. Qualitative data from their reflections on the walk participants suggested that they wanted to learn more about the nature in their greenspace and to take more time to notice the different natural elements of the greenspace, and that they would use the greenspace differently now they were aware of new parts of the greenspace and particularly visit areas with more natural features more. Participants also identified specific features they saw as enabling use and future use of different areas within a greenspace. Therefore, I show that although quantitatively perceptions of greenspaces did not change after a walk, qualitative data shows the walk did have impact on intentions associated with greenspace behaviour. Therefore, to maximise wellbeing, use, satisfaction and nature connection I recommend interventions that involve guided walks that focus on natural features and educational information about greenspace wildlife and local history and culture.

6.2 Overarching themes

In the following section, I discuss some overarching themes emerging across thesis chapters these include biodiversity, greenspace quality, importance of informal greenspaces and social context of greenspaces.

Urban greenspace biodiversity

I will first discuss the role of biodiversity for urban greenspaces (including small informal spaces). This project moved beyond simple quantification of biodiversity in urban greenspaces to take a multidisciplinary and multidimensional view of the impact that urban greenspace biodiversity has on ecosystem services, disservices, and relationships with health and wellbeing. I also recognise that urban greenspaces offer opportunities for urban biodiversity and are key to underpinning the ecosystem services.

I found that stakeholders involved in the project valued biodiversity in greenspaces and wanted to include biodiversity in the descriptions for defining greenspace when reporting (Chapter 2). These biodiversity metrics included habitat extent and mix, vegetation community, species richness and abundance. This finding demonstrates that greenspace stakeholders, from a range of background and disciplines, include biodiversity in their definition of greenspace alongside the social and spatial descriptors. Stakeholders also wanted to record an individual's connection with nature and environmental awareness and identity for greenspace project evaluation. I highlight consensus from the stakeholders that greenspaces offer opportunities for nature connection and therefore they agreed that this should be measured in future greenspace research. These findings build on previous research that found that although evidence on greenspace biodiversity and health and wellbeing is growing this element of green is still neglected in health studies (Lovell et al., 2014; Lai et al., 2019; Knobel et al., 2019; Lovell et al., 2020). This thesis included biodiversity as a measure of green as a standard through each of the chapters.

The most common measure of greenspace exposure and access is using a measure of 'greenness' called the Normalized Difference Vegetation Index (NDVI) (Jarvis et al., 2020). To my knowledge at time of writing, this is the only study to explore the species richness and health outcomes at a population scale. I showed that not all greenspaces should be treated as equal in analysis because biodiversity (species richness) may have a link to health outcomes (Chapter 3). This result supports previous findings that more diverse areas promote wellbeing, while lower wellbeing was found with a lack of biodiversity (Wood et al., 2018; Wyles et al., 2019; Cameron et al., 2020; Methorst et al., 2021; Knight et al., 2022). In an exploratory study, I found a positive association between biodiversity and health, where children were less likely to have unhealthy-low birthweights but, in contrast to previous literature, higher species richness was also associated with lower wellbeing and higher severity of depression. The biodiversity in the most common greenspace feature (amenity grass) surrounding individuals' homes has high species richness scores but these are dominated by spontaneous vegetation offering a lack of visual diversity in colour and composition (which has been shown to impact wellbeing Hoyle et al., 2017) and also tended to be of low user quality. These low-quality areas may be acting as a disservice to wellbeing. It should also be noted that this study took place in a deprived area and there are specific social and individual determinants of greenspace use in the study population (Cronin-de-Chavez et al., 2019). I recognise that biodiversity may play an enabling or limiting role in greenspace use and health and wellbeing outcomes but the community also raised the prevalence of social factors such as safety, high population density, racism and anti-social behaviour that may contribute towards wellbeing. Therefore, I propose that even if biodiversity was acting as a positive impact it may not overcome these social and economic challenges in a deprived area. However, I did find that a lack of green/biodiversity negatively affected health, for example, healthy birthweight was less likely for those with a greater number of grey streets and high birthweight was more likely with a greater number of grey streets. Therefore, I propose the relationship between biodiversity and health and wellbeing outcomes needs to be explored further as the presence of the right biodiversity of suitable quality could promote health and wellbeing and a lack of green or biodiversity is potentially a negative influence.

In observational studies exploring health and greenspaces, biodiversity is often overlooked. I found some associations between biodiversity (species richness) and physical activity (Chapter 4). Higher species richness, particularly tree species richness was associated with higher observations of sedentary activity. This may be linked to the restorative nature of biodiversity and park users seeking more diverse areas to sit and relax or to picnic (Kaplan and Kaplan, 1989; Wood et al., 2018; Knobel et al., 2021; Marselle et al., 2021). However, biodiversity (species richness of birds, bees, butterflies and trees) did not have an association with the number of observed users. Instead, those spaces with higher total species richness had similar numbers of users observed compared to those spaces with lower total species richness. Previous research has shown that, if designed correctly, even small greenspaces can attract similar numbers of users and offer health and wellbeing benefits (especially if they have a playground)(Nordh et al., 2009; Nordh and Østby, 2013; Cohen et al., 2014; Rupprecht and Byrne, 2014).

When comparing areas within a single greenspace (playground to woods in the same greenspace), there were fewer walking observations in areas with higher total species richness and plant species richness (such as woods)(Chapter 4). Tree and bird species richness and bird abundance had no significant relationship with activity levels. However, more people were observed in areas with higher tree species richness compared to other features. Although the use of the most biodiverse area (woods) was low, participants said they wanted to use these areas more. Participants also spoke about wanting to use other features (trees, water, and open space) and recognised the potential for these features if barriers such as litter and safety concerns were reduced. These findings were explored further in Chapter 5, where I explored the perceptions of park features with multiple dimensions to unpick the relationship between biodiversity and safety, attractiveness, nature connection and wellbeing. In Chapter 5, the participants greatly valued biodiversity (trees, water, rocks, flowers, birds and pollinators) and expressed wanting more of particular features such as flowers and wanting to use more natural areas (such as wood edge, woods and water) but quality and perceived safety were barriers to use. There was consensus in good scores for the following features across participants grass, pitch, scrub, wood and wood edge across all the dimensions, some less natural features were valued too but did not score as high across all dimensions. After a walk in the greenspace, participants said that they intended to use the greenspace differently to notice and learn more about wildlife and use natural areas more, demonstrating the value greenspace users placed on natural features during visits. I explore some of the implications and possible interventions in the 'implications for greenspace design and management section' below.

In summary, I explore an aspect of greenspaces that is often neglected and assumed to be similar across greenspaces. Here, I show that community members and greenspace stakeholders (academic, delivery partners, community workers and local government) value biodiversity. Biodiversity was highlighted as key component of a definition of greenspace and an important for future project design and evaluation. Biodiversity based interventions were also requested (both to increase biodiversity or remove/manage overgrown unpleasant elements such as spontaneous vegetation or pests). I show that there are relationships between biodiversity and use; poor-quality biodiverse areas acting as a barrier vs well-maintained areas with intermediate management are perceived as enablers to park use (Bjerke et al., 2006; Jorgensen and Anthopoulou, 2007; Hofmann et al., 2012; Qiu et al., 2013; Weber et al., 2014; Lindemann-Matthies and Matthies, 2018). However, when exploring the relationship between biodiversity and specific health outcomes the pattern is less clear. For example, low quality greenspace (with high prevalence of spontaneous vegetation and pest species) and an absence of green (grey spaces instead) may influence wellbeing negatively while higher species richness may influence physical activity levels. I also show that a walk where participants are asked to notice and comment on biodiversity aspects of a greenspace had a significant positive impact on wellbeing and noticing flowers even of informal spontaneous vegetation species were mentioned by participants as key attractive features but they did request more flowers in formal planting and dedicated intentional wildflower areas. The relationship between greenspace access, exposure and use with health and wellbeing is complex and further research should explore differences across specific features.

I propose that greenspace biodiversity should not be assumed as equal in future greenspace studies as particular features might add or detract to wellbeing and health depending on quality, composition and location in a greenspace or in relation to an individual's home. However, collecting this data can be resource intensive, I explore the required resources needed to carryout data collection in 'limitations and directions for further research' section below.

Greenspace quality

It was clear from the qualitative data that greenspace quality greatly influences perceptions of greenspace and participants offered suggestions for how to improve greenspace quality and the observational data found more greenspace users in greenspaces of a higher quality (Chapter 4 and 5). After walking in the greenspace some participants stated that they felt sad to see litter or a deterioration of the greenspace quality and that their wellbeing was lower after a visit to a greenspace of low quality (Chapter 5). However, greenspace quality from a user perspective was not a good predictor for health outcomes using epidemiology data. It is important to note that quality (NEST) scores were at the low to mid-range of the scale across the majority of the greenspaces in the study area which were dominated by amenity grass. Greenspace user quality was the second highest ranked descriptors by all greenspace stakeholders demonstrating the importance for projects and community members and therefore it should be monitored, reported and included in future research (Chapter 2). Comparing results from areas with higher quality to areas with lower quality will offer further insight into relationships between greenspace quality and health and wellbeing outcomes.

Including informal greenspaces in health and wellbeing research

Urban greenspace studies can assume there is a false dichotomy between grey space and greenspace across a city. However, in reality there is a more complex landscape with smaller informal greenspaces and grey spaces distributed across the city. This study includes these smaller greenspaces alongside larger greenspaces. Smaller informal spaces can offer opportunities for biodiversity and people (and are disproportionately used by children for play spaces) but are often excluded from studies on greenspace and health that only include larger greenspace (Rupprecht and Byrne, 2014; Cox et al., 2018; White et al., 2019; Jarvis et al., 2020; Rojas-Rueda et al., 2021; Dobson et al., 2021). Informal greenspaces also offer the benefit of space without prescribed uses and allow for creative use of a space (Rupprecht and Byrne, 2014). Small spaces with particular features such as water or play equipment can promote health and wellbeing (Nordh et al., 2009; Cohen et al., 2014; Rupprecht and Byrne, 2014). Therefore, in Chapter 3, I included all greenspaces surrounding and individual’s home when measuring greenspace access. One key motivation for this was the knowledge that even though these smaller spaces can offer benefits for people and biodiversity, in reality to support these benefits greater resources and management are required. These spaces are often small patches of grass which support spontaneous vegetation and if overgrown offer little opportunity for use or play and can be a negative feature that collects litter and dog poo with potential for negative impacts for health and wellbeing. These issues are likely to be worse in more deprived areas where fewer resources are available to maintain quality and this study took place in some of England’s most deprived areas.

My fieldwork recorded the biodiversity and user quality of a range of informal greenspaces across the study area to explore the above phenomenon that is often neglected in other studies. There was a mix of biodiversity and use depending on the management, I observed very small informal spaces being used to play or negatively used (drinking and drugs) and neglected with litter and dog poo. From this data, I could identify small-scale and street-level opportunities for improving greenspaces. Using the birth cohort data, I also found that grey streets (devoid of green features) negatively impacted health (for example, healthy birthweight was less likely for those with a greater number of grey streets)(Chapter 3). A pattern was emerging, that informal greenspace is better than no greenspace (Chapter 3) but low-quality informal greenspaces can have negative impacts on wellbeing and perceptions of a local area (see Chapter 4) and therefore to maximise health and wellbeing benefits of the most prevalent type of urban greenspaces special care should be taken to maintain quality. Participants in this thesis indicated that part of increasing the quality of these informal greenspaces would include biodiversity interventions such as trees or flowers to attract birds and pollinators (Chapter 4). These findings led to some very small-scale interventions that addressed the negatives and facilitated the positive uses of the greenspace. The evaluation of the effectiveness of interventions for health and wellbeing is to follow after the completion of this thesis but it is key to note that these informal greenspace interventions (that were co-designed and supported by local residents) often involved increasing biodiversity (such as planting trees or wildflowers or feeding birds) and making play spaces and maintaining flexibility for use. Some of these interventions that were informed by data from this thesis are discussed in the 'implications for greenspace design and management' section below.

Social and community environment

Another recurring theme was that the social environment greatly influenced the use and perception of a greenspace. Some greenspaces had "friends of" groups, local organisation groups (such as a litter picking group) and other informal groups (such as a mothers walking group) that made the park feel safer and participants greatly valued the presence of these groups of people in parks even if they did not participate in them (Chapter 4). The general feeling of friendliness, community ownership and care was recognised when these groups were present (Chapter 4). On the opposite end of the spectrum, greenspaces lacking these social elements were seen as less safe and users were more likely to experience anti-social behaviours or incivilities such as litter, broken glass or sharps (Chapter 4). Community members asked for interventions to increase safety and community cohesion to complement the structural changes (Chapters 4 and 5). These suggestions demonstrate that having greenspaces close and accessible doesn't equate to use, indeed poor-quality parks with low social cohesion can have low use. However, I observed playgrounds as an enabling feature because even when playgrounds were deemed to be of poor quality or in greenspaces perceived as unsafe there was still high observed use of this part of the greenspace but low use of other parts of the greenspace was often observed. Interventions should target safety and community cohesion across other spaces of the greenspace and surrounding community spaces to increase use and health and wellbeing benefits and improve perceptions of the greenspace.

In summary, greenspaces of all sizes can affect health and wellbeing, but it should not be assumed that greenspaces would have positive effects or that every greenspace will have the same impact on health and wellbeing. There can be win-win features for greenspace design as a study that took place in some of the same greenspaces in Bradford found that species richness was high in greenspaces with higher user quality (Wood et al., 2018). Although the Wood et al., (2018) study didn't include the informal greenspaces which may be displaying a different pattern where poor quality greenspaces can have a negative impact, the authors showed that greenspace biodiversity can promote wellbeing across all ages, genders and ethnicities. I cannot determine which of user quality, biodiversity or safety are more or less important than each other for determining greenspace use and associated outcomes but I can show that all are valued by communities and stakeholders and should be included in future greenspace research. Even when taking a multidimensional approach to greenspace features, it wasn't clear which had the most influence on perceptions and use. For example perceived safety, attractiveness, nature connection, satisfaction or perceived biodiversity were all important on influence participants use and perceptions of the greenspace (Chapter 5). Careful management can create win-win opportunities through the presence and maintenance of park features (natural areas such as open grass fields, woods and water and other features such as playgrounds and cafes)(Chapter 5). These multiple dimensions contribute perceptions of greenspace quality and may influence use of the greenspace or areas within the greenspace (Chapter 4 and 5). Therefore, there is potential however to improve greenspaces (inducing smaller informal spaces) through interventions to increase user quality and biodiversity to create win-win spaces for communities, child play and nature. I explore some suggestions based on data from this thesis in the 'implications for greenspace design and management' section below.

6.3 Implications for greenspace design and management

This thesis explored particular features that were barriers and enablers to park use, and receiving benefits from urban greenspace. Data from this thesis was used as evidence to inform the co-design of the greenspace interventions in the study area as part of the Better Start Bradford Better Place Project. In the following section, I will offer some insights for urban greenspace design and management, using data from this thesis including responses from rich qualitative data, co-design groups and observations of greenspace use. I also highlight the associated examples of interventions from the Better Start Bradford Better Place Project, these interventions were informed by the data collected for this thesis and aimed to address problems and maximize benefits for communities and biodiversity in the study area. However, the evaluation of the 'after' impacts of the interventions is ongoing and began after the completion of this thesis. Therefore, this section offers reflections on data from this thesis and the associated interventions that followed in terms of their design and aims, rather than evaluating intervention impacts or offering formal recommendations (especially as interventions should be co-designed to meet local community needs and aspirations).

Connecting greenspaces and street-level green

It was apparent that the study area offered opportunities to create green routes between existing greenspaces and key local amenities (such as the town centre, places of worship, medical centres, nurseries, schools and libraries). During co-design and engagement with the community 'greenways' (routes with high-quality greenspaces) were requested (Chapter 4). Parents expressed that overgrown or untidy vegetation was a barrier to walking routes to or getting into greenspaces and using greenspaces (especially informal greenspaces) (Chapters 4 and 5). This community feedback initiated clearing key routes between greenspaces and putting opportunities for play, especially natural play in small informal greenspaces or streets (Figure 6.1, Figure 6.2 and Figure 6.3). The Better Place Project demonstrates the value of small informal and street-level green from a community perspective. Interventions were then designed to enable the use of informal spaces and make green routes. Some examples of interventions were clearing vegetation, wildflower and tree planting, bulb planting, adding playful paths, nature-inspired sculptures, barefoot sensory paths and markings on streets for games (Figure 6.1, Figure 6.2 and Figure 6.3). These interventions address identified barriers around aesthetics, lack of play provision and safety (removing vegetation, litter and sharps). They also increase biodiversity while providing play spaces (as requested in Chapter 4). Co-design with the community also led to community art installations, casts of local children's feet and large mosaics being installed along the routes (Figure 6.2, Figure 6.3 and Figure 6.4)(as requested in Chapters 4 and 5). Engagement activities around generating ideas for interventions, making art or casts and planting helped to demonstrate how spaces could be improved, used and cared for by the community. These interventions also aimed to address some barriers to greenspace use that were experienced on the way to parks by creating safe and attractive routes to greenspaces and between them (Figure 6.4)(Chapter 4).

Figure 6.1. An example of a small-scale intervention requested through co-design to create a cut-through and waiting space into a play space with natural features. This intervention also addressed community concerns about litter and overgrown vegetation.

Figure 6.2. This is an example of a playful street design to help join greenspaces by creating routes with opportunities for play or connection with nature.

Figure 6.3. An example of making playful greenspaces near schools to enable younger siblings to play in these greenspaces during pick-up times. This intervention created playful moments along a route between several greenspaces.

Figure 6.4. A specific issue in one route between greenspaces was this unattractive fencing and it made community members feel unsafe travelling between spaces, so a local art installation was put in place to make the route feel safer.

Creating safe spaces outside fenced playgrounds

Both observational and qualitative data showed that playgrounds were a heavily used feature of greenspaces (Chapters 4 and 5). Community members (participants of the qualitative data collection) greatly value the playground but expressed wanting to spend time outside of fenced playground areas and in other parts of greenspaces, especially more natural areas (Chapters 4 and 5). However, common barriers were safety (such as antisocial behaviour) or the features being unsafe themselves such as dirty water or overgrown vegetation (Chapters 4 and 5). For physical activity and restorative benefits, greenspaces could address these safety issues of natural features by installing railings, cleaning water features and cutting back vegetation (Chapters 4 and 5). Cutting back or managing dense vegetation can make users feel safer, particularly if they can see through the vegetation to the other side (Burgess, 1995; Jansson et al., 2013). Previous literature has found that park users prefer 'half open' parks compared to areas of complex vegetation and park users show a preference for a medium level of human influence on natural features (trees, water, vegetation and planting) and dislike uniformity, artificial modifications and very mature vegetation (Qiu et al., 2013; Rupprecht and Byrne, 2014).

Paths that were flat (such as tarmac) and pushchair-friendly made spaces outside of the playground more accessible and feel safer (Chapters 4 and 5). Observational and qualitative data showed that paths in the greenspace and particularly through natural areas (with trees or water) were well-used and enabling features (Chapters 4 and 5). Previous studies have found that paths are a well-used park feature (Reed et al., 2008; Shores and West, 2010; Besenyi et al., 2013; Van Hecke et al., 2017). However, muddy paths were a barrier to use by the participants. Yet a previous study found that users of natural surface trails were active for longer and were more vigorous than those using paved trails (Reed et al., 2008). If natural surface trails could be introduced in an accessible way, there is potential for higher activity and activity for longer. Another study found that adding patterns and markings to paths could increase activity (Igel et al., 2020). Observational data showed that tree-lined paths, in particular, had high use in the study area, so future interventions could plant trees along paths to increase use (Chapter 4). Note that tree-lined paths had single trees spread out along the path so the visibility was clear, promoting perceived safety (Chapter 5). Some interventions in the area involved skipping rope trials and markings on the paths so that children could play games on these features (Figure 6.2). Using greenspaces and increasing people's movement through these spaces could promote positive health outcomes such as increased duration or intensity of physical activity which is a key priority for greenspace stakeholders.

One intervention, in particular, focused on a wooded area of a large greenspace that was locally known as 'The Roughs' due to the perception of anti-social behaviour there. The intervention involved clearing litter, removing and cutting back vegetation, and installing nature-based sculptures and signs (Figure 6.5). The area was opened up drastically with clear sight through the woods and pushchair-friendly paths (Figure 6.5). After installation, delivery partners raised that the sculptures, Goldilocks and the three bears, proved almost too popular with so many children holding hands with the bears that the fingers were worn down and on one occasion a finger fell off.

While structural changes to the greenspace can increase use, programming activities can significantly increase park use by girls and is often a gap in provision (Tester and Baker, 2009; Cole et al., 2023). Therefore, having organised or supervised activities in open spaces could potentially increase the use of these areas and promote higher activity levels (Jorgensen and Anthopoulou, 2007; Floyd et al., 2011; Baran et al., 2014; Hillier et al., 2016). Interventions in the study area also included engagement activities such as guided walks, litter picks, planting and outdoor story time.

Figure 6.5. Shows the area of woods that were opened up by cutting back vegetation and installing even paths and a sculpture trail. A) shows the dense vegetation and overgrown path, B) and C) show the formal path and cutback vegetation

Improving playgrounds

Playgrounds were the most used feature and participants often said they felt safe in the playground, as there were physical fences and they were away from safety concerns such as anti-social behaviour or dogs (Chapter 4). Although moderate to vigorous activity was observed in playgrounds, this was predominantly for children 5-11 years (Chapter 4). Adults and younger siblings were often sedentary (Chapter 4). Future playground designs could encourage play activities that require active movement of both children and adults simultaneously. Some of the engagement activities organised in the study area were built on creating games that adults could play with children inside and outside of the playground. Interventions in the area increased provision of equipment for 0-4-year-olds, putting in equipment such as swings that parents and children could use at the same time and encouraging the use of other parts of greenspaces for more active play through organised activities and free idea packs for parents (Figure 6.6).

From a very small sample of 0-4-year-old observations, when they were observed in playgrounds they were often in pushchairs or parent's arms (Chapter 4). While this is only a snapshot of use, a future design could do more to have equipment multiple ages can use. I also observed more vigorous 0-4-year-olds in open space with trees compared to playgrounds (Chapter 4). Therefore, interventions of the Better Place Project also included encouraging use outside of playgrounds by improving the safety of spaces and providing opportunities for natural play.

Natural play opportunities

Community members (during engagement events and co-design activities) and participants of the photo-voice study expressed the desire to use natural features more for play (Chapters 4 and 5). Suggestions for interventions included, cleaning water features, water play, adding paths, wood/log-based play features, trees to climb, boulders to climb, mounds to run up or roll down, sensory barefoot features (grass and sand pits) and places to hide (Chapter 4 and 5). Therefore, interventions in this study involved most of the above features and where more traditional play equipment was put in, bespoke nature-based designs were used (such as a caterpillar slide)(Figure 6.7). Community members also said a barrier to use was not knowing what to do in areas outside of the playground, so activity cards and ideas were created to demonstrate play ideas for natural features and ideas were included on signage in parks and on the project website so they were easily accessible (Figure 6.6). Additional work was carried out with community organisations (such as between Forest Schools and nurseries) to provide or share equipment for natural play such as wellington boots, coats and tarpaulin.

A commissioned project associated with the Better Start Bradford Programme established Forest Schools with local nurseries and took place in the greenspaces in the study area and trained local community members (parents and carers). Forest School activities can promote physical development and build stamina through whole-body movements such as walking, traversing rugged terrain, collecting and moving materials and building or destroying structures (O'Brien and Murray, 2007). These benefits were most noticeable for those under 5 years (O'Brien and Murray, 2007). Therefore, future greenspace projects may want to explore establishing forest schools alongside natural play features and opportunities as this has a dual purpose of teaching people how to use the space (about natural features and physical activity) but also increased use of the greenspace makes people feel safer. However, participants in the study area noted that in some of the greenspaces the Forest School session had to be paused or moved locations entirely due to anti-social behaviour, so future greenspace decision-makers may need to address these safety concerns alongside establishment (Chapter 4).

Figure 6.6. Examples of flashcards to generate ideas for early years to play in greenspaces across the seasons.

Figure 6.7. An example of the nature-inspired play equipment for 0-3-year-olds in the study area shows the play equipment, which is a bespoke caterpillar slide

Finding greenspaces and navigating within greenspaces

Participants also expressed that sometimes it was difficult to know where greenspaces were and which greenspaces they could use and which parts of a greenspace they could use (Cronin-de-Chavez et al., 2019)(Chapters 4 and 5). Even if there were signs in the space, they often detailed what was not allowed such as feeding the birds (Chapter 4). In fact, some greenspace users were unaware of specific natural features in the greenspace as they only ever used the playground and missed that there was a pond, meadows or woodlands to explore in the same greenspace (Chapter 5). Therefore, interventions in the study area included a friendly map of the greenspaces across the area and then a more detailed map for most of the sites (Figure 6.8, Figure 6.9 and Figure 6.10). The maps are accessible on the Better Place Project website and signs for each space. The signs in greenspaces were improved to show a map of the greenspace and offer ideas for how to use the space, this aimed to change the dominance of signs telling people what wasn't allowed in the greenspace to friendly welcoming signs (Figure 6.10). For example, the new signs say things like can you 'hop like a frog across the hopping stones?' compared to 'don't feed the birds as you could be fined'.

Figure 6.8. This is a simplified and welcoming map of the greenspaces within the study area.

Figure 6.9. This is a friendly map of the greenspace sculpture trail within the study area.

Figure 6.10. This is a picture of the greenspace sign and ideas for how to use different features.

Vacant or previously developed spaces in greenspaces

Participants and community members often highlighted spaces in the greenspaces that had previously been used for other purposes and were now left vacant or overgrown (Chapters 4 and 5). Community members referenced planting or structures that were used differently in the spaces historically (Chapters 4 and 5). Some of these areas were where formal planting had previously been and so community members asked for planting to be established again but to be accompanied by educational resources such as names of plants and wildlife (Chapters 4 and 5). For example, there was an area in a park established in the Victorian era that used to have glasshouses for flowers and community members said they'd like to see something like this in that spot or to use the area (which was tarmac) for new uses rather than it stand vacant (Chapter 5). While it stood vacant it appeared to be uncared for and seen as a negative feature that could signal anti-social behaviour (Chapter 5). The interventions for this area involved community co-design and turning the space into a scooter track for children (Figure 6.11). Future greenspace interventions can be sympathetic to previous uses but could also recognise opportunities for new development based on existing vacant areas and local context and culture (Fischer et al., 2018a). Future studies could explore the historical uses and contexts of the greenspace as suggested by Mcintyre et al. (2000).

Figure 6.11. An example of a tarmac space that community members identified as being a vacant and unattractive area of the greenspace. This vacant space was developed into a scooter and balance bike track intended for children under four years old.

Figure 6.12. An example of a greenspace that was not used due to motorbikes driving on the grass but new fencing and boulders would prevent vehicle access to promote use by the local community.

Social environment and urban greenspaces

As previously highlighted in this thesis, the issues around community cohesion and safety were major barriers to using particular areas in greenspaces that emerged in the qualitative data in this thesis (Chapters 4 and 5). Therefore, structural changes like removing hazards, damaged equipment, sharps, litter and overgrown vegetation and installing vehicle barriers and boulders aimed to address some of these issues (Figure 6.12) (Chapters 4 and 5). These changes are key to enabling use, and promoting health and wellbeing benefits but can potentially create a trade-off with biodiversity, as vegetation is cleared or thinned. Participants wanted to have visibility and said that open space was safe but with the right physical and social environment other park features would be used (Chapters 4 and 5). Community members in some areas also requested CCTV and additional lighting to be installed but this was outside the scope of the Better Start Bradford Project. Therefore, alternative ways of making a greenspace feel safer were developed. Interventions that aimed to increase the use of greenspaces through engagement events, establishing friends of groups and community group use (such as outside story time, litter picking and walking groups) were also implemented in the study area. This was an emerging theme from the qualitative data, the more park users present the safer they felt (Chapters 4 and 5). To maximise the use of a whole greenspace and promote physical activity, interventions to encourage use outside of playgrounds were implemented. One major intervention was the introduction of a roaming park ranger that covered all greenspaces in the study area. Their role was to tidy vegetation, remove litter and vandalism, report or fix broken equipment and offer opportunities for activities and learning in greenspaces outside of playground areas. The ranger was established after my data collection and evaluation is to follow but future greenspace projects should explore both structural and non-structural interventions for improving safety and community cohesion to increase greenspace use.

6.4 Limitations and directions for further research

The methodological limitations, potential bias and any underlying assumptions are described within each chapter. However, some overarching limitations and directions for future research are described below.

Exclusion of private greenspaces

I strived to include all publicly accessible greenspaces within the analysis and a strength of the study is that I included smaller informal spaces where other research excludes these. However, a key group of urban greenspaces was not included in the study: gardens. I recognise that gardens can offer health and wellbeing benefits and resources for urban biodiversity. Publicly accessible greenspaces were the only type of spaces that were to receive greenspace interventions through the Better Start Bradford Better Place Project (that this thesis aimed to evaluate). However, where data on gardens was available, I included it (for example, I included the presence/absence of gardens and time spent in the garden in the analysis in Chapter 3). Therefore, I recommend that future research could explore the impact of gardens alongside publicly accessible urban greenspaces on health and wellbeing outcomes.

Greenspace quality

I included a measure of greenspace quality, which is often omitted in studies or based only on size (Knobel et al., 2019). I chose the Natural Environment Scoring Tool (NEST; Gidlow et al.,

2018) as it covered multiple aspects of quality and was easy to administer in the field so that academics and delivery partners could collect the data (Knobel et al., 2019). There were always multiple visits and multiple assessors present for these scores so that averages could be taken across visits and assessors. However, although the assessors, particularly the delivery partners, were very familiar with the greenspaces across the study area, the data could have been improved by getting responses from community members (the greenspace users themselves). Due to large and ongoing community engagement in the study area associated with the programme and a long-standing sister research programme, I was asked to be strategic about the level of engagement this study pursued to avoid overburdening the local community. Therefore, I collected community member perspectives on quality through the photo-voice methodology as it produces rich in-depth responses about park quality, perceptions, and user behaviour. As a result, I did not ask any community members to accompany us or carry out NEST scoring of the greenspaces independently. However, future projects could have greenspace users assess greenspace quality and compare them with the scores from researchers and delivery partners.

Greenspace use

Due to practicalities associated with resources required to capture greenspace use it was only possible to observe greenspace use in the summer months. I recognise that from previous literature and data from greenspace use surveys in the area that there are fewer users in the colder seasons and so there is a gap in health and wellbeing provision for greenspace users in these months. Therefore, when designing the interventions with community members use across all seasons were explored, their suggestions included having shared clothing and equipment for multiple seasons, sheltered and shaded areas, water play, tree planting, seasonal festivals and light trails. I recommend that future greenspace projects should explore use and intervention effectiveness across all seasons.

One limitation of the methods used to capture greenspace use was that it only provides a snapshot of use. However, using the qualitative data, I gathered insights into past and aspirations for future use but this data is limited to a small sample size in Chapter 4. Therefore, in Chapter 5 I scaled up the sample size and across greenspaces in the area. The intended study design for the evaluation of the project (and this thesis) of controlled, before-and-after would capture changes in use after interventions (however, this was changed due to the coronavirus pandemic). Therefore, I recommend that future research should use a controlled before-and-after design and mixed methods data collection to explore greenspace use to capture insights into changes in the space and use over time from a community perspective before-and-after interventions.

Using either buffer or network methods to measure greenspace exposure and access does not offer accurate insights into an individual's daily movement (Christensen et al., 2021; Christensen et al., 2022). As both of these methods were applied in this thesis, the limitations of the study methods and suggestions for improving on these methods are discussed in Chapter 3. However, it should be noted that more representative measures of an individual's greenspace use could be gained through adapting methods or applying alternative data collection methods such as GPS-tracked movements (often available from phones are fitness devices), buffer ellipses, Individualized Residential Exposure Models (IREM) and the VERITAS questionnaire (Chaix et al., 2012; Kestens et al., 2018; Hasanzadeh et al., 2018; Laatikainen et al., 2018; Christensen et al., 2022). As demonstrated previously in the literature and this thesis (Chapters 4 and 5), biodiversity and nature connection can play a role in park use. Therefore, contact (time spent in nature) and connection with nature (using tools such as the connectedness to nature scale Mayer and Frantz, 2004) should also be collected as part of greenspace use measures (Holland et al., 2021).

6.5 Conclusion

This thesis has aimed to produce useful and accessible evidence that is relevant for academics, practitioners (greenspace delivery partners) and local government while highlighting the perspectives of local greenspace community members and opportunities to support greenspace biodiversity. The evidence in this thesis demonstrates that greenspaces mean different things to a wide variety of stakeholders and across disciplines. I find consensus across a small group of stakeholders to provide a standard approach to describing greenspaces. I demonstrate that greenspaces are not always used and if they are, they are not always used in the same way. It can't be assumed that people close to a greenspace will use that greenspace and gain any associated benefits from that use. The use of features within a greenspace also varies across age, gender and naturalness. High use of playgrounds and low use of wood features were observed. Therefore, a greenspace cannot be studied as a single unit as there will be areas of high and low use depending on greenspace features. Once identified, the areas of low use can be targeted for interventions.

I demonstrate that greenness and dimensions of greenspace such as biodiversity have a relationship with health and wellbeing outcomes. Although not always in the anticipated direction, for example, low wellbeing and more severe depression in areas with higher surrounding species richness. Therefore, the relationship is complex and requires further investigation. I began to explore this further by collecting rich qualitative data that expanded on barriers and enablers to use of greenspaces and features within greenspaces. Trade-offs between biodiversity and attractiveness, safety and wellbeing were highlighted. However, I show that greenspace users value biodiversity and natural features and often asked for it to be increased by adding more trees or flowers to the greenspace. To overcome some of the trade-offs with safety and attractiveness, management of features should maintain a level of neatness or explain the value of untidy features (such as benefits for unmown areas for pollinators). Potential win-win features that can be a foundation for providing benefits across safety, wellbeing, attractiveness and biodiversity include formal planting, grass, pitch, scrub, wood and wood edge.

I also demonstrate that the size of a greenspace had little impact on use, as smaller greenspaces with play equipment or opportunities can have similar numbers of users. Therefore, small greenspaces should be included in future analysis and not be overlooked for interventions aimed at increasing health, wellbeing and biodiversity. Even a small 100m stretch of grass can offer benefits for play, wellbeing and biodiversity. A network of small informal greenspaces can also enable physical activity through movement to and then subsequent use of connected larger greenspaces.

Although greenspace quality was important to community members, the relationship between greenspace quality and use and health and wellbeing outcomes was unclear. Here I show that spaces with low to medium quality are still used by community members and that there were no relationships between user quality and health or wellbeing outcomes when using epidemiological methods. Use of low-quality greenspaces often occurred if a playground was present but the other areas of the space were avoided. Low quality did not appear to have a significant negative effect on health or wellbeing but it was raised as a barrier to use in qualitative data. Perhaps the disservices of low-quality greenspace were negated by avoiding them and their use? It is clear however that high-quality greenspaces were attractive and valued by community members. A before-and-after design could explore if increasing the quality of surrounding greenspace promoted health and wellbeing benefits and use.

Future research that explores the relationship between a broader spectrum of biodiversity and across a gradient of socio-economic groups will help explore the relationship between biodiversity and health outcomes. Future research should take into account that being close to a green space does not guarantee use or if people use greenspaces that there is a physical activity benefit. To understand the relationship between an individual and surrounding greenspace using their self-defined neighbourhood or data from wearable devices on where, when and how active they were. However, it is clear that using epidemiological methods that surrounding greenness promotes some positive health outcomes while a lack of surrounding green can promote poor health so the presence of surrounding greenspace is key for offering potential for use, health and wellbeing benefits but special care should be taken to maintain a high standard otherwise there can be negative outcomes.

My thesis demonstrates the multidimensional nature of greenspaces and their study and why an interdisciplinary, mixed-methods and place-based approach can offer unique valuable insights into the relationship between greenspace, biodiversity and health and wellbeing (which are often omitted from other study designs).

7 References

Abbasi, B., Pourmirzaei, M., Hariri, S., Heshmat, R., Qorbani, M., Dadvand, P. and Kelishadi, R. 2020. Subjective Proximity to Green Spaces and Blood Pressure in Children and Adolescents: The CASPIAN-V Study. *Journal of Environmental and Public Health*. [Online]. **2020**, p.e8886241. [Accessed 29 January 2021]. Available from: https://www.hindawi.com/journals/jeph/2020/8886241/.

Aerts, R., Dujardin, S., Nemery, B., Van Nieuwenhuyse, A., Van Orshoven, J., Aerts, J.-M., Somers, B., Hendrickx, M., Bruffaerts, N., Bauwelinck, M., Casas, L., Demoury, C., Plusquin, M. and Nawrot, T.S. 2020. Residential green space and medication sales for childhood asthma: A longitudinal ecological study in Belgium. *Environmental Research*. **189**, p.109914.

Aerts, R., Honnay, O. and Van Nieuwenhuyse, A. 2018. Biodiversity and human health: mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin*. **127**(1), pp.5–22.

Alcock, I., White, M.P., Wheeler, B.W., Fleming, L.E. and Depledge, M.H. 2014. Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas. *Environmental Science & Technology*. **48**(2), pp.1247–1255.

Alirol, E., Getaz, L., Stoll, B., Chappuis, F. and Loutan, L. 2011. Urbanisation and infectious diseases in a globalised world. *The Lancet Infectious Diseases*. **11**(2), pp.131–141.

Altman, D.G. 1999. *Practical statistics for medical research*. New York: Chapman & Hall/CRC Press.

Amarawickrama, S., Singhapathirana, P. and Rajapaksha, N. 2015. Defining Urban Sprawl in the Sri Lankan Context: With Special Reference to the Colombo Metropolitan Region. *Journal of Asian and African Studies*. **50**(5), pp.590–614.

American College of Obstetricians and Gynecologists 2018. ACOG Practice Bulletin No. 190: Gestational Diabetes Mellitus. *Obstetrics & Gynecology*. **131**(2), p.e49.

American College of Obstetricians and Gynecologists 2020. Macrosomia: ACOG Practice Bulletin, Number 216. *Obstetrics & Gynecology*. **135**(1), p.e18.

Annerstedt, M. and Währborg, P. 2011. Nature-assisted therapy: Systematic review of controlled and observational studies. *Scandinavian Journal of Public Health*. **39**(4), pp.371–388.

Bakolis, I., Hammoud, R., Smythe, M., Gibbons, J., Davidson, N., Tognin, S. and Mechelli, A. 2018. Urban Mind: Using Smartphone Technologies to Investigate the Impact of Nature on Mental Well-Being in Real Time. *Bioscience*. **68**(2), pp.134–145.

Baldock, K.C.R., Goddard, M.A., Hicks, D.M., Kunin, W.E., Mitschunas, N., Osgathorpe, L.M., Potts, S.G., Robertson, K.M., Scott, A.V., Stone, G.N., Vaughan, I.P. and Memmott, J. 2015. Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B: Biological Sciences*. **282**(1803), p.20142849.

Baran, P.K., Smith, W.R., Moore, R.C., Floyd, M.F., Bocarro, J.N., Cosco, N.G. and Danninger, T.M. 2014. Park Use Among Youth and Adults: Examination of Individual, Social, and Urban Form Factors. *Environment and Behavior*. **46**(6), pp.768–800.

Barton, H. and Grant, M. 2006. A health map for the local human habitat. *Journal of the Royal Society for the Promotion of Health*. **126**(6), pp.252–253.

Beaglehole, R., Bonita, R., Horton, R., Adams, C., Alleyne, G., Asaria, P., Baugh, V., Bekedam, H., Billo, N., Casswell, S., Cecchini, M., Colagiuri, R., Colagiuri, S., Collins, T., Ebrahim, S., Engelgau, M., Galea, G., Gaziano, T., Geneau, R., Haines, A., Hospedales, J., Jha, P., Keeling, A., Leeder, S., Lincoln, P., McKee, M., Mackay, J., Magnusson, R., Moodie, R., Mwatsama, M., Nishtar, S., Norrving, B., Patterson, D., Piot, P., Ralston, J., Rani, M., Reddy, K.S., Sassi, F., Sheron, N., Stuckler, D., Suh, I., Torode, J., Varghese, C. and Watt, J. 2011. Priority actions for the non-communicable disease crisis. *The Lancet*. **377**(9775), pp.1438–1447.

Bebbington, A. 2005. The ability of A-level students to name plants. *Journal of Biological Education*. **39**(2), pp.63–67.

Beery, T. and Jørgensen, K.A. 2018. Children in nature: sensory engagement and the experience of biodiversity. *Environmental Education Research*. **24**(1), pp.13–25.

de Bell, S., Graham, H. and White, P.C.L. 2018. The role of managed natural spaces in connecting people with urban nature: a comparison of local user, researcher, and provider views. *Urban Ecosystems*. **21**(5), pp.875–886.

Bell, S., Thompson, C.W. and Travlou, P. 2003. Contested views of freedom and control: Children, teenagers and urban fringe woodlands in Central Scotland. *Urban Forestry & Urban Greening*. **2**(2), pp.87–100.

Beninde, J., Veith, M. and Hochkirch, A. 2015. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters*. **18**(6), pp.581–592.

Besenyi, G.M., Kaczynski, A.T., Wilhelm Stanis, S.A. and Vaughan, K.B. 2013. Demographic variations in observed energy expenditure across park activity areas. *Preventive Medicine*. **56**(1), pp.79–81.

Better Start Bradford 2023. Better Place. *Better Start Bradford*. [Online]. [Accessed 22 April 2023]. Available from: https://www.betterstartbradford.org.uk/project/family/better-place/.

Bhaskaran, K., Douglas, I., Forbes, H., dos-Santos-Silva, I., Leon, D.A. and Smeeth, L. 2014. Body-mass index and risk of 22 specific cancers: a population-based cohort study of 5·24 million UK adults. *Lancet*. **384**(9945), pp.755–765.

Birch, J., Rishbeth, C. and Payne, S.R. 2020. Nature doesn't judge you – how urban nature supports young people's mental health and wellbeing in a diverse UK city. *Health & Place*. **62**, p.102296.

Bissell, D. 2009. Visualising everyday geographies: practices of vision through travel-time. *Transactions of the Institute of British Geographers*. **34**(1), pp.42–60.

Bixler, R.D. and Floyd, M.F. 1997. Nature is Scary, Disgusting, and Uncomfortable. *Environment and Behavior*. **29**(4), pp.443–467.

Bjerke, T., Østdahl, T., Thrane, C. and Strumse, E. 2006. Vegetation density of urban parks and perceived appropriateness for recreation. *Urban Forestry & Urban Greening*. **5**(1), pp.35–44.

Bocarro, J.N., Floyd, M., Moore, R., Baran, P., Danninger, T., Smith, W. and Cosco, N. 2009. Adaptation of the system for observing physical activity and recreation in communities (SOPARC) to assess age groupings of children. *Journal of Physical Activity and Health*. **6**(6), pp.699–707.

Bolund, P. and Hunhammar, S. 1999. Ecosystem services in urban areas. *Ecological Economics*. **29**(2), pp.293–301.

Bozkurt, M. and Woolley, H. 2020. Let's splash: Children's active and passive water play in constructed and natural water features in urban green spaces in Sheffield. *Urban Forestry & Urban Greening*. **52**, p.126696.

Bradford Metropolitan District Council 2016. Report of the Strategic Director of Health and Wellbeing to the meeting of the Health and Social Care Overview and Scrutiny Committee to be held on the 17th November 2016. [Accessed 21 October 2022]. Available from: https://bradford.moderngov.co.uk/documents/s12700/Hlt17NovDocQ.pdf.

Bradford Metropolitan District Council 2022a. Bradford Population. *Bradford Metropolitan District Council*. [Online]. [Accessed 21 October 2022]. Available from: https://ubd.bradford.gov.uk/about-us/population/.

Bradford Metropolitan District Council 2022b. Ward profiles 2022. *Bradford Metropolitan District Council*. [Online]. [Accessed 21 October 2022]. Available from: https://ubd.bradford.gov.uk/district-and-ward-profiles/ward-profiles-2022/.

Brauman, K.A., Garibaldi, L.A., Polasky, S., Aumeeruddy-Thomas, Y., Brancalion, P.H.S., DeClerck, F., Jacob, U., Mastrangelo, M.E., Nkongolo, N.V., Palang, H., Pérez-Méndez, N., Shannon, L.J., Shrestha, U.B., Strombom, E. and Verma, M. 2020. Global trends in nature's contributions to people. *Proceedings of the National Academy of Sciences*. **117**(51), pp.32799–32805.

Brindley, P., Cameron, R.W., Ersoy, E., Jorgensen, A. and Maheswaran, R. 2019. Is more always better? Exploring field survey and social media indicators of quality of urban greenspace, in relation to health. *Urban Forestry & Urban Greening*. **39**, pp.45–54.

Britton, E., Kindermann, G., Domegan, C. and Carlin, C. 2020. Blue care: a systematic review of blue space interventions for health and wellbeing. *Health Promotion International*. **35**(1), pp.50–69.

Browning, M. and Lee, K. 2017. Within What Distance Does "Greenness" Best Predict Physical Health? A Systematic Review of Articles with GIS Buffer Analyses across the Lifespan. *International Journal of Environmental Research and Public Health*. **14**(7), p.675.

Brussoni, M., Gibbons, R., Gray, C., Ishikawa, T., Sandseter, E.B.H., Bienenstock, A., Chabot, G., Fuselli, P., Herrington, S., Janssen, I., Pickett, W., Power, M., Stanger, N., Sampson, M. and Tremblay, M.S. 2015. What is the Relationship between Risky Outdoor Play and Health in Children? A Systematic Review. *International Journal of Environmental Research and Public Health*. **12**(6), pp.6423–6454.

Bryman, A. 2015. *Social Research Methods* 5th edition. Oxford; New York: OUP Oxford.

Budig, K., Diez, J., Conde, P., Sastre, M., Hernán, M. and Franco, M. 2018. Photovoice and empowerment: evaluating the transformative potential of a participatory action research project. *BMC Public Health*. **18**(1), p.432.

Burgess, J. 1995. *'Growing in confidence' – Understanding people's perceptions of urban fringe woodlands.* Cheltenham.: Countryside Commission.

Burnett, H., Olsen, J.R., Nicholls, N. and Mitchell, R. 2021. Change in time spent visiting and experiences of green space following restrictions on movement during the COVID-19 pandemic: a nationally representative cross-sectional study of UK adults. *BMJ Open*. **11**(3), p.e044067.

Cameron, R.W.F., Brindley, P., Mears, M., McEwan, K., Ferguson, F., Sheffield, D., Jorgensen, A., Riley, J., Goodrick, J., Ballard, L. and Richardson, M. 2020. Where the wild things are! Do urban green spaces with greater avian biodiversity promote more positive emotions in humans? *Urban Ecosystems*. **23**(2), pp.301–317.

Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P. and Sanesi, G. 2015. Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landscape and Urban Planning*. **134**, pp.221–228.

Carvell, C., Isaac, N., Jitlal, M., Peyton, J., Powney, G., Roy, D., Vanbergen, A., O'Connor, R., Jones, C., Kunin, B., Breeze, T., Garratt, M., Potts, S., Harvey, M., Ansine, J., Comont, R., Lee, P., Edwards, M., Roberts, S., Morris, R., Musgrove, A., Brereton, T., Hawes, C. and Roy, H. 2017. *Design and testing of a national pollinator and pollination monitoring framework* [Online]. Department for Environment, Food and Rural Affairs. [Accessed 26 January 2021]. Available from: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=19259.

Castellar, J.A.C., Popartan, L.A., Pueyo-Ros, J., Atanasova, N., Langergraber, G., Säumel, I., Corominas, L., Comas, J. and Acuña, V. 2021. Nature-based solutions in the urban context: terminology, classification and scoring for urban challenges and ecosystem services. *Science of The Total Environment*. **779**, p.146237.

Cavaleiro Rufo, J., Paciência, I., Hoffimann, E., Moreira, A., Barros, H. and Ribeiro, A.I. 2021. The neighbourhood natural environment is associated with asthma in children: A birth cohort study. *Allergy*. **76**(1), pp.348–358.

Chaix, B., Kestens, Y., Perchoux, C., Karusisi, N., Merlo, J. and Labadi, K. 2012. An Interactive Mapping Tool to Assess Individual Mobility Patterns in Neighborhood Studies. *American Journal of Preventive Medicine*. **43**(4), pp.440–450.

Colléony, A., Prévot, A.-C., Saint Jalme, M. and Clayton, S. 2017. What kind of landscape management can counteract the extinction of experience? *Landscape and Urban Planning*. **159**, pp.23–31.

Collier, B 2019. Black absence in green spaces. *The Ecologist*. [Online]. [Accessed 15 December 2023]. Available from: https://theecologist.org/2019/oct/10/black-absence-green-spaces.

Chow, B.C., McKenzie, T.L. and Sit, C.H.P. 2016. Public parks in Hong Kong: Characteristics of physical activity areas and their users. *International Journal of Environmental Research and Public Health*. **13**(7).

Christensen, A., Griffiths, C., Hobbs, M., Gorse, C. and Radley, D. 2021. Accuracy of buffers and self-drawn neighbourhoods in representing adolescent GPS measured activity spaces: An exploratory study. *Health & Place*. **69**, p.102569.

Christensen, A., Radley, D., Hobbs, M., Gorse, C. and Griffiths, C. 2022. Investigating how researcher-defined buffers and self-drawn neighbourhoods capture adolescent availability to physical activity facilities and greenspaces: An exploratory study. *Spatial and Spatio-temporal Epidemiology*. **43**, p.100538.

Coates, J.K. and Pimlott-Wilson, H. 2019. Learning while playing: Children's Forest School experiences in the UK. *British Educational Research Journal*. **45**(1), pp.21–40.

Cohen, D.A., Marsh, T., Williamson, S., Golinelli, D. and McKenzie, T.L. 2012. Impact and cost-effectiveness of family Fitness Zones: A natural experiment in urban public parks. *Health and Place*. **18**(1), pp.39–45.

Cohen, D.A., Marsh, T., Williamson, S., Han, B., Derose, K.P., Golinelli, D. and McKenzie, T.L. 2014. The potential for pocket parks to increase physical activity. *American Journal of Health Promotion*. **28**(SUPPL 3), pp.S19–S26.

Coldwell, D.F. and Evans, K.L. 2017. Contrasting effects of visiting urban green-space and the countryside on biodiversity knowledge and conservation support. *PLOS ONE*. **12**(3), p.e0174376.

Cole, S., Goodenough, J., Haniff, M., Hussain, N., Ibrahim, S., Jani, A., Jiggens, E., Khan, A., Langford, P., Moore, L., Montgomery, L., Rowe, R. and Skinner, S. 2023. *Greenspace & Us: A community insights project to understand barriers and enablers around access to greenspace for teenage girls in East Oxford.* Natural England, Oxfordshire County Council, Oxford Youth Enterprise, Name It Youth Project, RESOLVE Collective, Fig.studio, Oxford City Council and Oxford University.

Collas, L., Green, R.E., Ross, A., Wastell, J.H. and Balmford, A. 2017. Urban development, land sharing and land sparing: the importance of considering restoration. *Journal of Applied Ecology*. **54**(6), pp.1865–1873.

Collins, P.Y., Patel, V., Joestl, S.S., March, D., Insel, T.R., Daar, A.S., Bordin, I.A., Costello, E.J., Durkin, M., Fairburn, C., Glass, R.I., Hall, W., Huang, Y., Hyman, S.E., Jamison, K., Kaaya, S., Kapur, S., Kleinman, A., Ogunniyi, A., Otero-Ojeda, A., Poo, M.-M., Ravindranath, V., Sahakian, B.J., Saxena, S., Singer, P.A., Stein, D.J., Anderson, W., Dhansay, M.A., Ewart, W., Phillips, A., Shurin, S. and Walport, M. 2011. Grand challenges in global mental health. *Nature*. **475**(7354), pp.27–30.

Consonni, F., Buffa, B., Dianda, D., Manelli, F., Molinelli, M., Pizzocri, D. and Massari, M. 2014. Greenspace: towards a systematic, global and innovative evaluation of the environmental impact of space activities for a safe and sustainable space environment. *In*: Toronto, Canada.

Coombes, E., Jones, A.P. and Hillsdon, M. 2010. The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Social Science & Medicine (1982)*. **70**(6), pp.816–822.

Corbett, J., d'Angelo, C., Gangitano, L. and Freeman, J. 2018. Future of Health. *Rand Health Quarterly*. **7**(3), p.1.

Corley, E.A., Ahn, J.J., Kim, Y., Lucio, J., Rugland, E. and Molina, A.L. 2018. Conceptualizing Lenses, Dimensions, Constructs, and Indicators for Urban Park Quality. *Environmental Justice*. **11**(6), pp.208–221.

County Councils Network 2022. *County Budgets 2022-24 Counting the costs of inflation* [Online]. [Accessed 28 October 2022]. Available from: https://www.countycouncilsnetwork.org.uk/worse-than-austerity-councils-warn-that-any-cuts-to-their-budgets-next-year-would-mean-they-are-only-able-to-offer-the-bare-minimum-in-local-services/.

Cox, D.T.C., Hudson, H.L., Shanahan, D.F., Fuller, R.A. and Gaston, K.J. 2017. The rarity of direct experiences of nature in an urban population. *Landscape and Urban Planning*. **160**, pp.79–84.

Cox, D.T.C., Shanahan, D.F., Hudson, H.L., Fuller, R.A. and Gaston, K.J. 2018. The impact of urbanisation on nature dose and the implications for human health. *Landscape and Urban Planning*. **179**, pp.72–80.

Cracknell, D., Lovell, R, Wheeler, B, and White, M. 2019. *Demystifying Health Metrics, Valuing Nature Paper* [Online]. Available from: https://valuing-nature.net/sites/default/files/images/VNP19-DemystifyingHealthMetrics-A4-36pp-200dpi_0.pdf.

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F. and Oja, P. 2003. International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*. **35**(8), pp.1381–1395.

Craig, P., Cooper, C., Gunnell, D., Haw, S., Lawson, K., Macintyre, S., Ogilvie, D., Petticrew, M., Reeves, B., Sutton, M. and Thompson, S. 2012. Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. *Journal of Epidemiology and Community Health*. **66**(12), pp.1182–1186.

Crompton, J.L. 2013. The health rationale for urban parks in the nineteenth century in the USA. *World Leisure Journal*. **55**(4), pp.333–346.

Cronin-de-Chavez, A., Islam, S. and McEachan, R.R.C. 2019. Not a level playing field: A qualitative study exploring structural, community and individual determinants of greenspace use amongst low-income multi-ethnic families. *Health & Place*. **56**, pp.118–126.

Cutland, C.L., Lackritz, E.M., Mallett-Moore, T., Bardají, A., Chandrasekaran, R., Lahariya, C., Nisar, M.I., Tapia, M.D., Pathirana, J., Kochhar, S. and Muñoz, F.M. 2017. Low birth weight: Case definition & guidelines for data collection, analysis, and presentation of maternal immunization safety data. *Vaccine*. **35**(48Part A), pp.6492–6500.

Dadvand, P., de, N.A., Triguero, -Mas Margarita, Schembari, A., Cirach, M., Amoly, E., Figueras, F., Basaga, ña X., Ostro, B. and Nieuwenhuijsen, M. 2012. Surrounding Greenness and Exposure to Air Pollution During Pregnancy: An Analysis of Personal Monitoring Data. *Environmental Health Perspectives*. **120**(9), pp.1286–1290.

Dadvand, P., Villanueva, C.M., Font-Ribera, L., Martinez, D., Basagaña, X., Belmonte, J., Vrijheid, M., Gražulevičienė, R., Kogevinas, M. and Nieuwenhuijsen, M.J. 2014. Risks and benefits of green spaces for children: a cross-sectional study of associations with sedentary behavior, obesity, asthma, and allergy. *Environmental Health Perspectives*. **122**(12), pp.1329–1335.

Dadvand, P., Wright, J., Martinez, D., Basagaña, X., McEachan, R.R.C., Cirach, M., Gidlow, C.J., de Hoogh, K., Gražulevičienė, R. and Nieuwenhuijsen, M.J. 2014. Inequality, green spaces, and pregnant women: Roles of ethnicity and individual and neighbourhood socioeconomic status. *Environment International*. **71**, pp.101–108.

Dallimer, M., Irvine, K.N., Skinner, A.M.J., Davies, Z.G., Rouquette, J.R., Maltby, L.L., Warren, P.H., Armsworth, P.R. and Gaston, K.J. 2012. Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness. *BioScience*. **62**(1), pp.47–55.

Day, B.H. and Smith, G. 2018. *Outdoor Recreation Valuation (ORVal)*. Land, Environment, Economics and Policy (LEEP) Institute, Business School: University of Exeter.

Declet-Barreto, J., Brazel, A.J., Martin, C.A., Chow, W.T.L. and Harlan, S.L. 2013. Creating the park cool island in an inner-city neighborhood: heat mitigation strategy for Phoenix, AZ. *Urban Ecosystems*. **16**(3), pp.617–635.

Delgado-Capel, M. and Cariñanos, P. 2020. Towards a Standard Framework to Identify Green Infrastructure Key Elements in Dense Mediterranean Cities. *Forests*. **11**(12), p.1246.

DeMers, D. and Wachs, D. 2022. Physiology, Mean Arterial Pressure *In*: *StatPearls* [Online]. Treasure Island (FL): StatPearls Publishing. [Accessed 22 April 2022]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK538226/.

Department for Environment, Food & Rural Affairs 2023. *Environmental Improvement Plan 2023* [Online]. [Accessed 22 February 2023]. Available from: https://www.gov.uk/government/publications/environmental-improvement-plan.

Department for Environment, Food and Rural Affairs 2017. *A Green Future: Our 25 Year Plan to Improve the Environment.*

Department for Levelling Up, Housings & Communities 2021. *National Planning Policy Framework* [Online]. [Accessed 15 December 2023] Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1182995/NPPF_Sept_23.pdf.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., Oudenhoven, A.P.E. van, Plaat, F. van der, Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C.A., Hewitt, C.L., Keune, H., Lindley, S. and Shirayama, Y. 2018. Assessing nature's contributions to people. *Science*. **359**(6373), pp.270–272.

Dickerson, J., Bird, P.K., McEachan, R.R.C., Pickett, K.E., Waiblinger, D., Uphoff, E., Mason, D., Bryant, M., Bywater, T., Bowyer-Crane, C., Sahota, P., Small, N., Howell, M., Thornton, G., Astin, M., Lawlor, D.A. and Wright, J. 2016. Born in Bradford's Better Start: an experimental birth cohort study to evaluate the impact of early life interventions. *BMC Public Health*. **16**(1), p.711.

Dickerson, J., Bridges, S., Willan, K., Kelly, B., Moss, R.H., Lister, J., Netkitsing, C., Atkinson, A.L., Bird, P.K., Uphoff, E.P., Mason, D., Newsham, A., Waiblinger, D., Razaq, R., Ahern, S., Bryant, M., Blower, S.L., Pickett, K.E., McEachan, R.M. and Wright, J. 2022. Born in

Bradford's Better Start (BiBBS) interventional birth cohort study: Interim cohort profile [version 1; peer review: 1 approved]. *Wellcome Open Research*. (7), p.244.

Didan, K. 2015. *MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006 [Data set]* [Online]. NASA EOSDIS Land Processes DAAC. [Accessed 9 December 2022]. Available from: https://doi.org/10.5067/MODIS/MOD13Q1.006.

Dobson, J. 2018. From contest to context: urban green space and public policy. *People, Place and Policy Online*. **12**(2), pp.72–83.

Dobson, J., Birch, J., Brindley, P., Henneberry, J., McEwan, K., Mears, M., Richardson, M. and Jorgensen, A. 2021. The magic of the mundane: The vulnerable web of connections between urban nature and wellbeing. *Cities*. **108**, p.102989.

von Döhren, P. and Haase, D. 2015. Ecosystem disservices research: A review of the state of the art with a focus on cities. *Ecological Indicators*. **52**, pp.490–497.

Doick, K.J., Pediaditi, K., Moffat, A.J. and Hutchings, T.R. 2009. Defining the sustainability objectives of brownfield regeneration to greenspace. *International Journal of Management and Decision Making*. **10**(3–4), pp.282–302.

Dong, Y., Liu, H. and Zheng, T. 2021. Association between Green Space Structure and the Prevalence of Asthma: A Case Study of Toronto. *International Journal of Environmental Research and Public Health*. **18**(11), p.5852.

Dronavalli, M. and Thompson, S.C. 2015. A systematic review of measurement tools of health and well-being for evaluating community-based interventions. *J Epidemiol Community Health*. **69**(8), pp.805–815.

Dzhambov, A.M. and Dimitrova, D.D. 2015. Green spaces and environmental noise perception. *Urban Forestry & Urban Greening*. **14**(4), pp.1000–1008.

Dzhambov, A.M., Lercher, P., Rüdisser, J., Browning, M.H.E.M. and Markevych, I. 2021. Allergic symptoms in association with naturalness, greenness, and greyness: A cross-sectional study in schoolchildren in the Alps. *Environmental Research*. **198**, p.110456.

Early Intervention Foundation 2016. *The cost of late intervention: EIF analysis 2016* [Online]. [Accessed 11 March 2023]. Available from: https://www.eif.org.uk/report/the-cost-of-late-intervention-eif-analysis-2016.

EDINA Digimap 2018. *High Resolution (25cm) Vertical Aerial Imagery* [Online]. EDINA Aerial Digimap Service. [Accessed 8 March 2021]. Available from: https://digimap.edina.ac.uk>.

Escobedo, F.J., Kroeger, T. and Wagner, J.E. 2011. Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution*. **159**(8), pp.2078–2087.

Esser, P.R., Mueller, S. and Martin, S.F. 2019. Plant Allergen-Induced Contact Dermatitis. *Planta Medica*. **85**(7), pp.528–534.

Evans, J. and Jones, P. 2011. The walking interview: methodology, mobility and place. Applied Geography, 31(2), 849-858. *Applied Geography - APPL GEOGR*. **31**, pp.849–858.

Farinha-Marques, P., Fernandes, C., Guilherme, F., Lameiras, J.M., Alves, P. and Bunce, R.G.H. 2017. Urban Habitats Biodiversity Assessment (UrHBA): a standardized procedure for recording biodiversity and its spatial distribution in urban environments. *Landscape Ecology*. **32**(9), pp.1753–1770.

Feest, A., Aldred, T. and Jedamzik, K. 2009. Biodiversity Quality: a paradigm for biodiversity. *Nature Precedings*. **4**.

Feltynowski, M. 2023. Urban green spaces in land-use policy – types of data, sources of data and staff – the case of Poland. *Land Use Policy*. **127**, p.106570.

Ferguson, M., Roberts, H.E., McEachan, R.R.C. and Dallimer, M. 2018. Contrasting distributions of urban green infrastructure across social and ethno-racial groups. *Landscape and Urban Planning*. **175**, pp.136–148.

Fields in Trust. 2018. *Revaluing Parks and Green Spaces: Measuring their economic and wellbeing value to individuals*. London.

Filipe, A., Renedo, A. and Marston, C. 2017. The co-production of what? Knowledge, values, and social relations in health care. *PLOS Biology*. **15**(5), p.e2001403.

Fischer, L. K., Honold, J., Botzat, A., Brinkmeyer, D., Cvejić, R., Delshammar, T., Elands, B., Haase, D., Kabisch, N., Karle, S.J., Lafortezza, R., Nastran, M., Nielsen, A.B., van der Jagt, A.P., Vierikko, K. and Kowarik, I. 2018b. Recreational ecosystem services in European cities: Sociocultural and geographical contexts matter for park use. *Ecosystem Services*. **31**, pp.455–467.

Fischer, L. K., Honold, J., Cvejić, R., Delshammar, T., Hilbert, S., Lafortezza, R., Nastran, M., Nielsen, A.B., Pintar, M., van der Jagt, A.P.N. and Kowarik, I. 2018a. Beyond green: Broad support for biodiversity in multicultural European cities. *Global Environmental Change*. **49**, pp.35–45.

Fischer, L. K., Neuenkamp, L., Lampinen, J., Tuomi, M., Alday, J.G., Bucharova, A., Cancellieri, L., Casado-Arzuaga, I., Čeplová, N., Cerveró, L., Deák, B., Eriksson, O., Fellowes, M.D.E., Fernández de Manuel, B., Filibeck, G., González-Guzmán, A., Hinojosa, M.B., Kowarik, I., Lumbierres, B., Miguel, A., Pardo, R., Pons, X., Rodríguez-García, E., Schröder, R., Gaia Sperandii, M., Unterweger, P., Valkó, O., Vázquez, V. and Klaus, V.H. 2020. Public attitudes toward biodiversity-friendly greenspace management in Europe. *Conservation Letters*. **13**(4), p.e12718.

Fleiss, J.L., Myunghee Cho Paik, and Bruce Levin. 2003. *Statistical Methods for Rates and Proportions* 3rd ed. John Wiley; Sons, Inc.

Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D. and Viklander, M. 2015. SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal*. **12**(7), pp.525–542.

Floyd, M.F., Bocarro, J.N., Smith, W.R., Baran, P.K., Moore, R.C., Cosco, N.G., Edwards, M.B., Suau, L.J. and Fang, K. 2011. Park-based physical activity among children and adolescents. *American Journal of Preventive Medicine*. **41**(3), pp.258–265.

Forest Research 2017. Noise abatement. [Accessed 11 March 2023]. Available from: https://www.forestresearch.gov.uk/tools-and-resources/fthr/urban-regeneration-and-greenspace-partnership/greenspace-in-practice/benefits-of-greenspace/noise-abatement/.

Frantzeskaki, N. 2019. Seven lessons for planning nature-based solutions in cities. *Environmental Science & Policy*. **93**, pp.101–111.

Freedman, D.S., Katzmarzyk, P.T., Dietz, W.H., Srinivasan, S.R. and Berenson, G.S. 2009. Relation of body mass index and skinfold thicknesses to cardiovascular disease risk factors in children: the Bogalusa Heart Study. *The American Journal of Clinical Nutrition*. **90**(1), pp.210–216.

Frith, M.G. and Gedge, D. 2000. The black redstart in urban Britain: a conservation conundrum? *British Wildlife.* **8**, pp.381-388.

Fuertes, E., Markevych, I., von Berg, A., Bauer, C.-P., Berdel, D., Koletzko, S., Sugiri, D. and Heinrich, J. 2014. Greenness and allergies: evidence of differential associations in two areas in Germany. *Journal of Epidemiology and Community Health*. **68**(8), pp.787–790.

Fuertes, E., Markevych, I., Bowatte, G., Gruzieva, O., Gehring, U., Becker, A., Berdel, D., von Berg, A., Bergström, A., Brauer, M., Brunekreef, B., Brüske, I., Carlsten, C., Chan-Yeung, M., Dharmage, S.C., Hoffmann, B., Klümper, C., Koppelman, G.H., Kozyrskyj, A., Korek, M., Kull, I., Lodge, C., Lowe, A., MacIntyre, E., Pershagen, G., Standl, M., Sugiri, D., Wijga, A., MACS and Heinrich, J. 2016. Residential greenness is differentially associated with childhood allergic rhinitis and aeroallergen sensitization in seven birth cohorts. *Allergy*. **71**(10), pp.1461–1471.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H. and Gaston, K.J. 2007. Psychological benefits of greenspace increase with biodiversity. *Biology Letters*. **3**(4), pp.390–394.

Fuller, R.A., Tratalos, J. and Gaston, K.J. 2009. How many birds are there in a city of half a million people? *Diversity and Distributions*. **15**(2), pp.328–337.

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A. and Nieuwenhuijsen, M.J. 2015. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *International Journal of Environmental Research and Public Health*. **12**(4), pp.4354–4379.

Gascon, M., Zijlema, W., Vert, C., White, M.P. and Nieuwenhuijsen, M.J. 2017. Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies. *International Journal of Hygiene and Environmental Health*. **220**(8), pp.1207–1221.

Gaston, K.J. and Soga, M. 2020. Extinction of experience: The need to be more specific. *People and Nature*. **2**(3), pp.575–581.

Gatersleben, B. and Andrews, M. 2013. When walking in nature is not restorative—The role of prospect and refuge. *Health & Place*. **20**, pp.91–101.

Gellie, N.J.C., Mills, J.G., Breed, M.F. and Lowe, A.J. 2017. Revegetation rewilds the soil bacterial microbiome of an old field. *Molecular Ecology*. **26**(11), pp.2895–2904.

Gidlow, C., van Kempen, E., Smith, G., Triguero-Mas, M., Kruize, H., Gražulevičienė, R., Ellis, N., Hurst, G., Masterson, D., Cirach, M., van den Berg, M., Smart, W., Dėdelė, A., Maas, J. and Nieuwenhuijsen, M.J. 2018. Development of the natural environment scoring tool (NEST). *Urban Forestry & Urban Greening*. **29**, pp.322–333.

Global initiative for Asthma 2021. *Global Strategy for Asthma Management and Prevention* [Online]. [Accessed 8 February 2022]. Available from: https://ginasthma.org/wp-content/uploads/2021/05/GINA-Main-Report-2021-V2-WMS.pdf.

Grazuleviciene, R., Danileviciute, A., Dedele, A., Vencloviene, J., Andrusaityte, S., Uždanaviciute, I. and Nieuwenhuijsen, M.J. 2015. Surrounding greenness, proximity to city parks and pregnancy outcomes in Kaunas cohort study. *International Journal of Hygiene and Environmental Health*. **218**(3), pp.358–365.

Green Flag Award 2022. Green Flag Award. [Accessed 4 November 2022]. Available from: https://www.greenflagaward.org/.

Greenspace Scotland 2021. What is greenspace? *Greenspace Scotland*. [Online]. [Accessed 1 April 2021]. Available from: https://www.greenspacescotland.org.uk/what-is-greenspace#:~:text=Greenspaces%20are%20the%20'green%20lungs,the%20stresses%20of%20modern%20life.

Gundersen, V. and Helge Frivold, L. 2011. Naturally dead and downed wood in Norwegian boreal forests: public preferences and the effect of information. *Scandinavian Journal of Forest Research*. **26**(2), pp.110–119.

Gupta, K., Kumar, P., Pathan, S.K. and Sharma, K.P. 2012. Urban Neighborhood Green Index – A measure of green spaces in urban areas. *Landscape and Urban Planning*. **105**(3), pp.325–335.

Haahtela, T., Holgate, S., Pawankar, R., Akdis, C.A., Benjaponpitak, S., Caraballo, L., Demain, J., Portnoy, J. and von Hertzen, L. 2013. The biodiversity hypothesis and allergic disease: world allergy organization position statement. *The World Allergy Organization Journal*. **6**(1), p.3.

Haines-Young, R. and Potschin, M.B. 2018. *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure.* [Online]. [Accessed 15 April 2021]. Available from: www.cices.eu.

Hale, J.D., Fairbrass, A.J., Matthews, T.J. and Sadler, J.P. 2012. Habitat Composition and Connectivity Predicts Bat Presence and Activity at Foraging Sites in a Large UK Conurbation. *PLOS ONE*. **7**(3), p.e33300.

Hands, D.E. and Brown, R.D. 2002. Enhancing visual preference of ecological rehabilitation sites. *Landscape and Urban Planning*. **58**(1), pp.57–70.

Hanski, I., von Hertzen, L., Fyhrquist, N., Koskinen, K., Torppa, K., Laatikainen, T., Karisola, P., Auvinen, P., Paulin, L., Mäkelä, M.J., Vartiainen, E., Kosunen, T.U., Alenius, H. and Haahtela, T. 2012. Environmental biodiversity, human microbiota, and allergy are interrelated. *Proceedings of the National Academy of Sciences*. **109**(21), pp.8334–8339.

Harris, V., Kendal, D., Hahs, A.K. and Threlfall, C.G. 2018. Green space context and vegetation complexity shape people's preferences for urban public parks and residential gardens. *Landscape Research*. **43**(1), pp.150–162.

Hartig, T., Korpela, K., Evans, G.W. and Gärling, T. 1997. A measure of restorative quality in environments. *Scandinavian Housing and Planning Research*. **14**(4), pp.175–194.

Hasanzadeh, K., Rinne, T. and Kyttä, M. 2018. A place-based model of local activity spaces: individual place exposure and characteristics. *Journal of Geographical Systems*. **20**.

Hayhow, D., Burns, F., Eaton, M., Al Fulaij, N., August, T., Babey, L., Bacon, L., Bingham, C., Boswell, J., Boughey, K., Brereton, T., Brookman, E., Brooks, D., Bullock, D., Burke, O., Collis, M., Corbet, L., Cornish, N., De Massimi, S., Densham, J., Dunn, E., Elliott, S., Gent, T., Godber, J., Hamilton, S., Havery, S., Hawkins, S., Henney, J., Holmes, K., Hutchinson, N., Isaac, N., Johns, D., Macadam, C., Mathews, F., Nicolet, P., Noble, D., Outhwaite, C., Powney, G., Richardson, P., Roy, D., Sims, D., Smart, S., Stevenson, S., Stroud, R., Walker, K., Webb, J., Wynde, R. and Gregory, R. 2016. *State of Nature 2016* [Online]. The State of Nature partnership. [Accessed 15 April 2023]. Available from: https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/state-of-nature-uk-report-2016.pdf.

Hayhow, D., Eaton, M., Stanbury, A., Burns, F., Kirby, W., Bailey, N., Beckmann, B., Bedford, J., Boersch-Supan, P., Coomber, F., Dennis, E., Dolman, S., Dunn, E., Hall, J., Harrower, C., Hatfield, J., Hawley, J., Haysom, K., Hughes, J., Johns, D., Mathews, F., McQuatters-Gollop, A., Noble, D., Outhwaite, C., Pearce-Higgins, J., Pescott, O., Powney, G. and Symes, N. 2019. *The State of Nature 2019*. The State of Nature partnership.

Helbich, M., Yao, Y., Liu, Y., Zhang, J., Liu, P. and Wang, R. 2019. Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. *Environment International*. **126**, pp.107–117.

Helden, A.J. and Leather, S.R. 2004. Biodiversity on urban roundabouts—Hemiptera, management and the species–area relationship. *Basic and Applied Ecology*. **5**(4), pp.367–377.

Heo, S., Desai, M.U., Lowe, S.R. and Bell, M.L. 2021. Impact of Changed Use of Greenspace during COVID-19 Pandemic on Depression and Anxiety. *International Journal of Environmental Research and Public Health*. **18**(11), p.5842.

Hill, M.J., Biggs, J., Thornhill, I., Briers, R.A., Gledhill, D.G., White, J.C., Wood, P.J. and Hassall, C. 2017. Urban ponds as an aquatic biodiversity resource in modified landscapes. *Global Change Biology*. **23**(3), pp.986–999.

Hillier, A., Han, B., Eisenman, T.S., Evenson, K.R., McKenzie, T.L. and Cohen, D.A. 2016. Using systematic observations to understand conditions that promote interracial experiences in neighbourhood parks. *Urban Planning*. **1**(4), pp.51–64.

Hofmann, M., Westermann, J.R., Kowarik, I. and van der Meer, E. 2012. Perceptions of parks and urban derelict land by landscape planners and residents. *Urban Forestry & Urban Greening*. **11**(3), pp.303–312.

Holland, I., DeVille, N.V., Browning, M.H.E.M., Buehler, R.M., Hart, J.E., Hipp, J.A., Mitchell, R., Rakow, D.A., Schiff, J.E., White, M.P., Yin, J. and James, P. 2021. Measuring Nature Contact: A Narrative Review. *International Journal of Environmental Research and Public Health*. **18**(8), p.4092.

Honey-Rosés, J., Anguelovski, I., Chireh, V.K., Daher, C., Konijnendijk van den Bosch, C., Litt, J.S., Mawani, V., McCall, M.K., Orellana, A., Oscilowicz, E., Sánchez, U., Senbel, M., Tan, X., Villagomez, E., Zapata, O. and Nieuwenhuijsen, M.J. 2021. The impact of COVID-19 on public space: an early review of the emerging questions – design, perceptions and inequities. *Cities & Health*. **5**(sup1), pp.S263–S279.

Hope, D., Gries, C., Zhu, W., Fagan, W.F., Redman, C.L., Grimm, N.B., Nelson, A.L., Martin, C. and Kinzig, A. 2003. Socioeconomics drive urban plant diversity. *Proceedings of the National Academy of Sciences*. **100**(15), pp.8788–8792.

Houlden, V., Weich, S., Albuquerque, J.P. de, Jarvis, S. and Rees, K. 2018. The relationship between greenspace and the mental wellbeing of adults: A systematic review. *PLOS ONE*. **13**(9), p.e0203000.

Houlden, V., Weich, S. and Jarvis, S. 2017. A cross-sectional analysis of green space prevalence and mental wellbeing in England. *BMC Public Health*. **17**(1), p.460.

Hoyle, H. 2020. What Is Urban Nature and How Do We Perceive It? *In*: N. Dempsey and J. Dobson, eds. *Naturally Challenged: Contested Perceptions and Practices in Urban Green Spaces* [Online]. Cities and Nature. Cham: Springer International Publishing, pp.9–36. [Accessed 6 May 2021]. Available from: https://uwe-repository.worktribe.com/output/6634703/what-is-urban-nature-and-how-do-we-perceive-it.

Hoyle, H., Hitchmough, J. and Jorgensen, A. 2017. All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting. *Landscape and Urban Planning*. **164**, pp.109–123.

Hoyle, H., Jorgensen, A. and Hitchmough, J.D. 2019. What determines how we see nature? Perceptions of naturalness in designed urban green spaces. *People and Nature*. **1**(2), pp.167–180.

Hunter, A.J. and Luck, G.W. 2015. Defining and measuring the social-ecological quality of urban greenspace: a semi-systematic review. *Urban Ecosystems*. **18**(4), pp.1139–1163.

Hunter, R.F., Christian, H., Veitch, J., Astell-Burt, T., Hipp, J.A. and Schipperijn, J. 2015. The impact of interventions to promote physical activity in urban green space: a systematic review and recommendations for future research. *Social Science & Medicine (1982)*. **124**, pp.246–256.

Igel, U., Gausche, R., Krapf, A., Lück, M., Kiess, W. and Grande, G. 2020. "Movement-enhancing footpaths" – A natural experiment on street design and physical activity in children in a deprived district of Leipzig, Germany. *Preventive Medicine Reports*. **20**.

Im, J. 2019. Green Streets to Serve Urban Sustainability: Benefits and Typology. *Sustainability*. **11**(22), p.6483.

IMD 2019. English indices of deprivation 2019. *GOV.UK*. [Online]. [Accessed 21 October 2022]. Available from: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019.

Institute for Government 2020. Local government funding in England. [Accessed 11 February 2023]. Available from: https://www.instituteforgovernment.org.uk/explainer/local-government-funding-england.

Islam, M.Z., Johnston, J. and Sly, P.D. 2020. Green space and early childhood development: a systematic review. *Reviews on Environmental Health*. **35**(2), pp.189–200.

Jalkanen, J. and Vierikko, K. 2022. Viheralueiden elonkirjo: Asiantuntijakysely ja luonnon monimuotoisuuden laatumittaristo kaupunkisuunnittelun tueksi. *Terra*. **134**(4), pp.209–223.

James, G., Witten, D., Hastie, T. and Tibshirani, R. 2013. *An Introduction to Statistical Learning: with Applications in R* [Online]. New York: Springer-Verlag. [Accessed 25 January 2021]. Available from: https://www.springer.com/gp/book/9781461471370.

Jansen, M., Kamphuis, C.B.M., Pierik, F.H., Ettema, D.F. and Dijst, M.J. 2018. Neighborhood-based PA and its environmental correlates: A GIS- and GPS based cross-sectional study in the Netherlands. *BMC Public Health*. **18**(1).

Jansson, M., Fors, H., Lindgren, T. and Wiström, B. 2013. Perceived personal safety in relation to urban woodland vegetation – A review. *Urban Forestry & Urban Greening*. **12**(2), pp.127–133.

Jarvis, I., Gergel, S., Koehoorn, M. and van den Bosch, M. 2020. Greenspace access does not correspond to nature exposure: Measures of urban natural space with implications for health research. *Landscape and Urban Planning*. **194**, p.103686.

Jenkins, G.R., Yuen, H.K., Rose, E.J., Maher, A.I., Gregory, K.C. and Cotton, M.E. 2015. Disparities in Quality of Park Play Spaces between Two Cities with Diverse Income and Race/Ethnicity Composition: A Pilot Study. *International Journal of Environmental Research and Public Health*. **12**(7), pp.8009–8022.

Jerome, G., Mell, I. and Shaw, D. 2017. Re-defining the characteristics of environmental volunteering: Creating a typology of community-scale green infrastructure. *Environmental Research*. **158**, pp.399–408.

Jorgensen, A. and Anthopoulou, A. 2007. Enjoyment and fear in urban woodlands – Does age make a difference? *Urban Forestry & Urban Greening*. **6**(4), pp.267–278.

Jorgensen, A., Hitchmough, J. and Calvert, T. 2002. Woodland spaces and edges: their impact on perception of safety and preference. *Landscape and Urban Planning*. **60**(3), pp.135–150.

Kaplan, R. and Kaplan, S. 1989. *The Experience of Nature. A Psychological Perspective*. New York: Cambridge University Press.

Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L.J., Paus, T. and Berman, M.G. 2015. Neighborhood greenspace and health in a large urban center. *Scientific Reports*. **5**(1), p.11610.

Kelley, C., Mack, D.E. and Wilson, P.M. 2022. Does Physical Activity in Natural Outdoor Environments Improve Wellbeing? A Meta-Analysis. *Sports*. **10**(7), p.103.

Kelly, B. 2015. *Ethnic mixing in Bradford: Local dynamics of diversity. Evidence from the 2011 census.* Manchester, UK: University of Manchester.

Kestens, Y., Thierry, B., Shareck, M., Steinmetz-Wood, M. and Chaix, B. 2018. Integrating activity spaces in health research: Comparing the VERITAS activity space questionnaire with 7-day GPS tracking and prompted recall. *Spatial and Spatio-temporal Epidemiology*. **25**, pp.1–9.

Kettel, E.F., Gentle, L.K., Yarnell, R.W. and Quinn, J.L. 2019. Breeding performance of an apex predator, the peregrine falcon, across urban and rural landscapes. *Urban Ecosystems*. **22**(1), pp.117–125.

Keys, A., Fidanza, F., Karvonen, M.J., Kimura, N. and Taylor, H.L. 1972. Indices of relative weight and obesity. *Journal of Chronic Diseases*. **25**(6), pp.329–343.

Kim, Hyun-Jin, Min, J., Kim, Hye-Jin and Min, K. 2020. Association between green areas and allergic disease in Korean adults: a cross-sectional study. *Annals of Occupational and Environmental Medicine*. **32**, p.e5.

King, A.C., Winter, S.J., Sheats, J.L., Rosas, L.G., Buman, M.P., Salvo, D., Rodriguez, N.M., Seguin, R.A., Moran, M., Garber, R., Broderick, B., Zieff, S.G., Sarmiento, O.L., Gonzalez, S.A., Banchoff, A. and Dommarco, J.R. 2016. Leveraging Citizen Science and Information Technology for Population Physical Activity Promotion. *Translational journal of the American College of Sports Medicine*. **1**(4), pp.30–44.

King, D.K., Litt, J., Hale, J., Burniece, K.M. and Ross, C. 2015. 'The park a tree built': Evaluating how a park development project impacted where people play. *Urban Forestry and Urban Greening*. **14**(2), pp.293–299.

Klaus, V.H. and Kiehl, K. 2021. A conceptual framework for urban ecological restoration and rehabilitation. *Basic and Applied Ecology*. **52**, pp.82–94.

Klompmaker, J.O., Hoek, G., Bloemsma, L.D., Gehring, U., Strak, M., Wijga, A.H., van den Brink, C., Brunekreef, B., Lebret, E. and Janssen, N.A.H. 2018. Green space definition affects associations of green space with overweight and physical activity. *Environmental Research*. **160**, pp.531–540.

Knight, S.J., McClean, C.J. and White, P.C.L. 2022. The importance of ecological quality of public green and blue spaces for subjective well-being. *Landscape and Urban Planning*. **226**, p.104510.

Knobel, P., Dadvand, P. and Maneja-Zaragoza, R. 2019. A systematic review of multi-dimensional quality assessment tools for urban green spaces. *Health & Place*. **59**, p.102198.

Knobel, P., Maneja, R., Bartoll, X., Alonso, L., Bauwelinck, M., Valentin, A., Zijlema, W., Borrell, C., Nieuwenhuijsen, M. and Dadvand, P. 2021. Quality of urban green spaces influences residents' use of these spaces, physical activity, and overweight/obesity. *Environmental Pollution*. **271**, p.116393.

Koh, Y.F., Loc, H.H. and Park, E. 2022. Towards a "City in Nature": Evaluating the Cultural Ecosystem Services Approach Using Online Public Participation GIS to Support Urban Green Space Management. *Sustainability*. **14**(3), p.1499.

Kroenke, K., Spitzer, R.L. and Williams, J.B.W. 2001. The PHQ-9. *Journal of General Internal Medicine*. **16**(9), pp.606–613.

Kruize, H., van Kamp, I., van den Berg, M., van Kempen, E., Wendel-Vos, W., Ruijsbroek, A., Swart, W., Maas, J., Gidlow, C., Smith, G., Ellis, N., Hurst, G., Masterson, D., Triguero-Mas, M., Cirach, M., Gražulevičienė, R., van den Hazel, P. and Nieuwenhuijsen, M. 2020. Exploring mechanisms underlying the relationship between the natural outdoor environment and health and well-being – Results from the PHENOTYPE project. *Environment International*. **134**, p.105173.

La Rosa, D. and Privitera, R. 2013. Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. *Landscape and Urban Planning*. **109**(1), pp.94–106.

Laaidi, K., Zeghnoun, A., Dousset, B., Bretin, P., Vandentorren, S., Giraudet, E. and Beaudeau, P. 2012. The Impact of Heat Islands on Mortality in Paris during the August 2003 Heat Wave. *Environmental Health Perspectives*. **120**(2), pp.254–259.

Laatikainen, T.E., Hasanzadeh, K. and Kyttä, M. 2018. Capturing exposure in environmental health research: challenges and opportunities of different activity space models. *International Journal of Health Geographics*. **17**(1), p.29.

Lachowycz, K., Jones, A.P., Page, A.S., Wheeler, B.W. and Cooper, A.R. 2012. What can global positioning systems tell us about the contribution of different types of urban greenspace to children's physical activity? *Health & place*. **18**(3), pp.586–594.

Lai, H., Flies, E.J., Weinstein, P. and Woodward, A. 2019. The impact of green space and biodiversity on health. *Frontiers in Ecology and the Environment*. **17**(7), pp.383–390.

Lampinen, J., Tuomi, M., Fischer, L.K., Neuenkamp, L., Alday, J.G., Bucharova, A., Cancellieri, L., Casado-Arzuaga, I., Čeplová, N., Cerveró, L., Deák, B., Eriksson, O., Fellowes, M.D.E., de Manuel, B.F., Filibeck, G., González-Guzmán, A., Hinojosa, M.B., Kowarik, I., Lumbierres, B., Miguel, A., Pardo, R., Pons, X., Rodríguez-García, E., Schröder, R., Sperandii, M.G., Unterweger, P., Valkó, O., Vázquez, V. and Klaus, V.H. 2021. Acceptance of near-natural greenspace management relates to ecological and socio-cultural assigned values among European urbanites. *Basic and Applied Ecology*. **50**, pp.119–131.

Landis, J.R. and Koch, G.G. 1977. The measurement of observer agreement for categorical data. *Biometrics*. **33**(1), pp.159–174.

Latour, B. 1998. From the World of Science to the World of Research? *Science*. **280**(5361), pp.208–209.

Laven, D.N., Jewiss, J.L. and Mitchell, N.J. 2013. Toward Landscape-Scale Stewardship and Development: A Theoretical Framework of United States National Heritage Areas. *Society & Natural Resources*. **26**(7), pp.762–777.

Lee, A.C.K., Jordan, H.C. and Horsley, J. 2015. Value of urban green spaces in promoting healthy living and wellbeing: prospects for planning. *Risk Management and Healthcare Policy*. **8**, pp.131–137.

Legrand, F.D., Jeandet, P., Beaumont, F. and Polidori, G. 2022. Effects of Outdoor Walking on Positive and Negative Affect: Nature Contact Makes a Big Difference. *Frontiers in Behavioral Neuroscience*. **16**.

Lehtimäki, J., Karkman, A., Laatikainen, T., Paalanen, L., von Hertzen, L., Haahtela, T., Hanski, I. and Ruokolainen, L. 2017. Patterns in the skin microbiota differ in children and teenagers between rural and urban environments. *Scientific Reports*. **7**(1), p.45651.

Lemos, M.C. and Morehouse, B.J. 2005. The co-production of science and policy in integrated climate assessments. *Global Environmental Change*. **15**(1), pp.57–68.

Leslie, E., Sugiyama, T., Ierodiaconou, D. and Kremer, P. 2010. Perceived and objectively measured greenness of neighbourhoods: Are they measuring the same thing? *Landscape and Urban Planning*. **95**(1), pp.28–33.

Lin, B.B. and Fuller, R.A. 2013. Sharing or sparing? How should we grow the world's cities? *Journal of Applied Ecology*. **50**(5), pp.1161–1168.

Lindberg, M. and Schipperijn, J. 2015. Active use of urban park facilities - Expectations versus reality. *Urban Forestry and Urban Greening*. **14**(4), pp.909–918.

Lindemann-Matthies, P. 2006. Investigating Nature on the Way to School: Responses to an educational programme by teachers and their pupils. *International Journal of Science Education*. **28**(8), pp.895–918.

Lindemann-Matthies, P. and Bose, E. 2008. How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland. *Human Ecology*. **36**(5), pp.731–742.

Lindemann-Matthies, P., Junge, X. and Matthies, D. 2010. The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. *Biological Conservation*. **143**(1), pp.195–202.

Lindemann-Matthies, P. and Matthies, D. 2018. The influence of plant species richness on stress recovery of humans. *Web Ecology*. **18**(2), pp.121–128.

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H. and Taylor, W.W. 2007. Complexity of Coupled Human and Natural Systems. *Science*. **317**(5844), pp.1513–1516.

Lo, A.Y.H. and Jim, C.Y. 2010. Differential community effects on perception and use of urban greenspaces. *Cities*. **27**(6), pp.430–442.

Lokocz, E., Ryan, R.L. and Sadler, A.J. 2011. Motivations for land protection and stewardship: Exploring place attachment and rural landscape character in Massachusetts. *Landscape and Urban Planning*. **99**(2), pp.65–76.

Loukaitou-Sideris, A. and Sideris, A. 2009. What Brings Children to the Park? Analysis and Measurement of the Variables Affecting Children's Use of Parks. *Journal of the American Planning Association*. **76**(1), pp.89–107.

Loupa Ramos, I. 2010. 'Exploratory landscape scenarios' in the formulation of 'landscape quality objectives'. *Futures*. **42**(7), pp.682–692.

Lovasi, G.S., Jacobson, J.S., Quinn, J.W., Neckerman, K.M., Ashby-Thompson, M.N. and Rundle, A. 2011. Is the Environment Near Home and School Associated with Physical Activity and Adiposity of Urban Preschool Children? *Journal of Urban Health*. **88**(6), pp.1143–1157.

Lovell, R., Wheeler, B.W., Higgins, S.L., Irvine, K.N. and Depledge, M.H. 2014. A systematic review of the health and well-being benefits of biodiverse environments. *Journal of Toxicology and Environmental Health. Part B, Critical Reviews*. **17**(1), pp.1–20.

Lovell, R., White, M.P., Wheeler, B.W., Taylor, T. and Elliott, L. 2020. A rapid scoping review of health and wellbeing evidence for the Green Infrastructure Standards. *European Centre for Environment and Human Health, University of Exeter Medical School. For: Natural England, Department for the Environment, Food and Rural Affairs, Public Health England, and Ministry for Housing, Communities and Local Government, England.*

Lüdecke, D., Ben-Shachar, M.S., Patil, I., Waggoner, P. and Makowski, D. 2021. performance: An R Package for Assessment, Comparison and Testing of Statistical Models. *Journal of Open Source Software*. **6**(60), p.3139.

Luppino, F.S., de Wit, L.M., Bouvy, P.F., Stijnen, T., Cuijpers, P., Penninx, B.W.J.H. and Zitman, F.G. 2010. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. *Archives of General Psychiatry*. **67**(3), pp.220–229.

Luque-García, L., Corrales, A., Lertxundi, A., Díaz, S. and Ibarluzea, J. 2022. Does exposure to greenness improve children's neuropsychological development and mental health? A Navigation Guide systematic review of observational evidence for associations. *Environmental Research*. **206**, p.112599.

Lyytimäki, J. and Faehnle, M. 2009. Hopping on one leg – The challenge of ecosystem disservices for urban green management. *Urban Forestry & Urban Greening*., pp.309–315.

Lyytimäki, J., Petersen, L.K., Normander, B. and Bezák, P. 2008. Nature as a nuisance? Ecosystem services and disservices to urban lifestyle. *Environmental Sciences*. **5**(3), pp.161–172.

Maas, J., Verheij, R.A., Vries, S. de, Spreeuwenberg, P., Schellevis, F.G. and Groenewegen, P.P. 2009. Morbidity is related to a green living environment. *Journal of Epidemiology & Community Health*. **63**(12), pp.967–973.

Macpherson, H. 2016. Walking methods in landscape research: moving bodies, spaces of disclosure and rapport. *Landscape Research*. **41**(4), pp.425–432.

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., de Vries, S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M.J., Lupp, G., Richardson, E.A., Astell-Burt, T., Dimitrova, D., Feng, X., Sadeh, M., Standl, M., Heinrich, J. and Fuertes, E. 2017. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environmental Research*. **158**, pp.301–317.

Marmot, M., Allen, J., Boyce, T., Goldblatt, P. and Morrison, J. 2020. *Health Equity in England: The Marmot Review 10 Years On* [Online]. London: Institute of Health Equity. Available from: https://www.instituteofhealthequity.org/resources-reports/marmot-review-10-years-on.

Marmot, M., Allen J, Goldblatt P, Boyce T, McNeish D, Grady M, and Geddes I 2010. *Fair society, healthy lives: strategic review of health inequalities in England post 2010 (The Marmot Review)*. London.

Marquet, O., Aaron Hipp, J., Alberico, C., Huang, J.-H., Fry, D., Mazak, E., Lovasi, G.S. and Floyd, M.F. 2019. Park use preferences and physical activity among ethnic minority children in low-income neighborhoods in New York City. *Urban Forestry and Urban Greening*. **38**, pp.346–353.

Marselle, M.R., Bowler, D.E., Watzema, J., Eichenberg, D., Kirsten, T. and Bonn, A. 2020. Urban street tree biodiversity and antidepressant prescriptions. *Scientific Reports*. **10**(1), p.22445.

Marselle, M.R., Hartig, T., Cox, D.T.C., de Bell, S., Knapp, S., Lindley, S., Triguero-Mas, M., Böhning-Gaese, K., Braubach, M., Cook, P.A., de Vries, S., Heintz-Buschart, A., Hofmann, M., Irvine, K.N., Kabisch, N., Kolek, F., Kraemer, R., Markevych, I., Martens, D., Müller, R., Nieuwenhuijsen, M., Potts, J.M., Stadler, J., Walton, S., Warber, S.L. and Bonn, A. 2021. Pathways linking biodiversity to human health: A conceptual framework. *Environment International*. **150**, p.106420.

Matsler, A.M., Meerow, S., Mell, I.C. and Pavao-Zuckerman, M.A. 2021. A 'green' chameleon: Exploring the many disciplinary definitions, goals, and forms of "green infrastructure". *Landscape and Urban Planning*. **214**, p.104145.

Matthews, S.A. and Yang, T.-C. 2013. Spatial Polygamy and Contextual Exposures (SPACEs): Promoting Activity Space Approaches in Research on Place And Health. *American Behavioral Scientist*. **57**(8), pp.1057–1081.

Mayer, F.S. and Frantz, C.M. 2004. The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*. **24**(4), pp.503–515.

McCormack, G.R., Rock, M., Toohey, A.M. and Hignell, D. 2010. Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. *Health & Place*. **16**(4), pp.712–726.

McEachan, R.R.C., Prady, S.L., Smith, G., Fairley, L., Cabieses, B., Gidlow, C., Wright, J., Dadvand, P., van Gent, D. and Nieuwenhuijsen, M.J. 2016. The association between green space and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity. *Journal of Epidemiology and Community Health*. **70**(3), pp.253–259.

McEachan, R.R.C., Yang, T.C., Roberts, H., Pickett, K.E., Arseneau-Powell, D., Gidlow, C.J., Wright, J. and Nieuwenhuijsen, M. 2018. Availability, use of, and satisfaction with green space, and children's mental wellbeing at age 4 years in a multicultural, deprived, urban area: results from the Born in Bradford cohort study. *The Lancet Planetary Health*. **2**(6), pp.e244–e254.

McEwan, K., Richardson, M., Sheffield, D., Ferguson, F.J. and Brindley, P. 2021. Assessing the feasibility of public engagement in a smartphone app to improve well-being through nature connection (Evaluación de la factibilidad de la implicación ciudadana mediante una app de teléfonos inteligentes para mejorar el bienestar a través de la conexión con la naturaleza). *PsyEcology*. **12**(1), pp.45–75.

Mcintyre, N.E., Knowles-Yánez, K. and Hope, D. 2000. Urban ecology as an interdisciplinary field: differences in the use of "urban" between the social and natural sciences. *Urban Ecosystems*. **4**(1), pp.5–24.

McKenzie, T.L. and Cohen, D.A. 2006. *SOPARC (System for Observing Play and Recreation in Communities): Description and Procedures Manual.* [Online]. Available from: http://activelivingresearch.org/soparc-system-observing-play-and-recreation-communities.

McKinney, M.L. 2006. Urbanization as a major cause of biotic homogenization. *Biological Conservation*. **127**(3), pp.247–260.

McMahan, E.A., Cloud, J.M., Josh, P. and Scott, M. 2016. Nature With a Human Touch: Human-Induced Alteration Negatively Impacts Perceived Naturalness and Preferences for Natural Environments. *Ecopsychology*. **8**(1), pp.54–63.

Mears, M., Brindley, P., Baxter, I., Maheswaran, R. and Jorgensen, A. 2020. Neighbourhood greenspace influences on childhood obesity in Sheffield, UK. *Pediatric Obesity*. **15**(7), p.e12629.

Mears, M., Brindley, P., Jorgensen, A., Ersoy, E. and Maheswaran, R. 2019. Greenspace spatial characteristics and human health in an urban environment: An epidemiological study using landscape metrics in Sheffield, UK. *Ecological Indicators*. **106**, p.105464.

Mears, M., Brindley, P., Jorgensen, A. and Maheswaran, R. 2020. Population-level linkages between urban greenspace and health inequality: The case for using multiple indicators of neighbourhood greenspace. *Health & Place*. **62**, p.102284.

Mears, M., Brindley, P., Maheswaran, R. and Jorgensen, A. 2019. Understanding the socioeconomic equity of publicly accessible greenspace distribution: The example of Sheffield, UK. *Geoforum*. **103**, pp.126–137.

Mebrahtu, T.F., Feltbower, R.G. and Parslow, R.C. 2016. Incidence and Burden of Wheezing Disorders, Eczema, and Rhinitis in Children: findings from the Born in Bradford Cohort. *Paediatric and Perinatal Epidemiology*. **30**(6), pp.594–602.

Methorst, J., Rehdanz, K., Mueller, T., Hansjürgens, B., Bonn, A. and Böhning-Gaese, K. 2021. The importance of species diversity for human well-being in Europe. *Ecological Economics*. **181**, p.106917.

Meyer-Grandbastien, A., Burel, F., Hellier, E. and Bergerot, B. 2020. A step towards understanding the relationship between species diversity and psychological restoration of visitors in urban green spaces using landscape heterogeneity. *Landscape and Urban Planning*. **195**, p.103728.

Mhuireach, G., Johnson, B.R., Altrichter, A.E., Ladau, J., Meadow, J.F., Pollard, K.S. and Green, J.L. 2016. Urban greenness influences airborne bacterial community composition. *Science of The Total Environment*. **571**, pp.680–687.

Middleton, J. 2010. Sense and the city: exploring the embodied geographies of urban walking. *Social & Cultural Geography*. **11**(6), pp.575–596.

Middleton, J. 2018. The socialities of everyday urban walking and the ‘right to the city’. *Urban Studies*. **55**(2), pp.296–315.

Millennium Ecosystem Assessment 2005. *A Report of the Millennium Ecosystem Assessment. Ecosystems and Human Well-Being*. Washington DC: Island Press.

Miller, J.R. 2005. Biodiversity conservation and the extinction of experience. *Trends in Ecology & Evolution*. **20**(8), pp.430–434.

Milligan, C. and Bingley, A. 2007. Restorative places or scary spaces? The impact of woodland on the mental well-being of young adults. *Health & Place*. **13**(4), pp.799–811.

Mills, J.G., Weinstein, P., Gellie, N.J.C., Weyrich, L.S., Lowe, A.J. and Breed, M.F. 2017. Urban habitat restoration provides a human health benefit through microbiome rewilding: the Microbiome Rewilding Hypothesis. *Restoration Ecology*. **25**(6), pp.866–872.

Millward, H., Spinney, J. and Scott, D. 2013. Active-transport walking behavior: destinations, durations, distances. *Journal of Transport Geography*. **28**, pp.101–110.

Ministry of Housing, Communities & Local Government 2019. English indices of deprivation 2019. *GOV.UK*. [Online]. [Accessed 14 February 2023]. Available from: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019.

Mitchell, R. and Popham, F. 2008. Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet*. **372**(9650), pp.1655–1660.

Morton, R.D., Marston, C.G., O'Neil, A.W. and Rowland, C.S. 2020. *Land Cover Map 2019 (land parcels, GB)* [Online]. NERC Environmental Information Data Centre. [Accessed 18 June 2021]. Available from: https://doi.org/10.5285/44c23778-4a73-4a8f-875f-89b23b91ecf8.

Mouratidis, K. 2019. The impact of urban tree cover on perceived safety. *Urban Forestry & Urban Greening*. **44**, p.126434.

Mu, B. and Li, X. 2020. Research on sustainable development of urban green infrastructure based on social ecosystem framework. *International Journal of Environmental Technology and Management*. **23**(2–4), pp.138–148.

Mytton, O.T., Townsend, N., Rutter, H. and Foster, C. 2012. Green space and physical activity: an observational study using Health Survey for England data. *Health & Place*. **18**(5), pp.1034–1041.

Nassauer, J.I. 1995. Messy Ecosystems, Orderly Frames. *Landscape Journal*. **14**(2), pp.161–170.

Natural England 2018. Children's visits to natural environments: new evidence. *GOV.UK*. [Online]. [Accessed 16 March 2023]. Available from: https://www.gov.uk/government/news/childrens-visits-to-natural-environments-new-evidence.

Natural England 2009. Monitor of Engagement with the Natural Environment (MENE). *GOV.UK*. [Online]. [Accessed 7 July 2021]. Available from: https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results.

Natural England 2010. *"Nature nearby" accessible natural greenspace guidance*. Peterborough: Natural England.

Natural England 2022. The People and Nature Survey. *GOV.UK*. [Online]. [Accessed 22 February 2023]. Available from: https://www.gov.uk/government/collections/people-and-nature-survey-for-england.

Ng Fat, L., Scholes, S., Boniface, S., Mindell, J. and Stewart-Brown, S. 2017. Evaluating and establishing national norms for mental wellbeing using the short Warwick–Edinburgh Mental Well-being Scale (SWEMWBS): Findings from the Health Survey for England. *Quality of Life Research: An International Journal of Quality of Life Aspects of Treatment, Care & Rehabilitation*. **26**, pp.1129–1144.

Ng, Warlow, Chrishanthan, Ellis, and Walls 2000. Preliminary criteria for the definition of allergic rhinitis: a systematic evaluation of clinical parameters in a disease cohort (I). *Clinical & Experimental Allergy*. **30**(9), pp.1314–1331.

Niedźwiecka-Filipiak, I., Gubański, J., Podolska, A., Rubaszek, J. and Witkiewicz, A. 2022. Potential Elements of Green Infrastructure (PeGI) Inside the Core of the Village (CoV):

A Case Study of Wrocław Functional Area (WFA) in Poland. *Sustainability*. **14**(3), p.1611.

Nielsen, A.B., van den Bosch, M., Maruthaveeran, S. and van den Bosch, C.K. 2014. Species richness in urban parks and its drivers: A review of empirical evidence. *Urban Ecosystems*. **17**(1), pp.305–327.

Nieuwenhuijsen, M.J. 2016. Urban and transport planning, environmental exposures and health-new concepts, methods and tools to improve health in cities. *Environmental Health*. **15**(1), p.S38.

Nisbet, E. and Zelenski, J. 2013. The NR-6: a new brief measure of nature relatedness. *Frontiers in Psychology*. **4**.

Nordh, H., Hartig, T., Hagerhall, C.M. and Fry, G. 2009. Components of small urban parks that predict the possibility for restoration. *Urban Forestry & Urban Greening*. **8**(4), pp.225–235.

Nordh, H. and Østby, K. 2013. Pocket parks for people – A study of park design and use. *Urban Forestry & Urban Greening*. **12**(1), pp.12–17.

Nowak, D.J., Greenfield, E.J., Hoehn, R.E. and Lapoint, E. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*. **178**, pp.229–236.

O'Brien, L. and Murray, R. 2007. Forest School and its impacts on young children: Case studies in Britain. *Urban Forestry & Urban Greening*. **6**(4), pp.249–265.

Ode Sang, Å., Fry, G., Tveit, M.S., Messager, P. and Miller, D. 2009. Indicators of perceived naturalness as drivers of landscape preference. *Journal of Environmental Management*. **90**(1), pp.375–383.

Ode Sang, Å., Knez, I., Gunnarsson, B. and Hedblom, M. 2016. The effects of naturalness, gender, and age on how urban green space is perceived and used. *Urban Forestry & Urban Greening*. **18**, pp.268–276.

Ode Sang, Å. and Tveit, M.S. 2013. Perceptions of stewardship in Norwegian agricultural landscapes. *Land Use Policy*. **31**, pp.557–564.

Odum, E.P. 1997. *Ecology : a bridge between science and society.* [Online] 3rd ed. Oxford: Oxford University Press Inc. [Accessed 10 February 2023]. Available from: https://www.cabdirect.org/cabdirect/abstract/19980613652.

Office for Health Improvement and Disparities, OHID 2021. Public health profiles. [Accessed 21 October 2022]. Available from: https://fingertips.phe.org.uk/.

Oh, R.R.Y., Fielding, K.S., Carrasco, R.L. and Fuller, R.A. 2020. No evidence of an extinction of experience or emotional disconnect from nature in urban Singapore. *People and Nature*. **2**(4), pp.1196–1209.

Ojala, A., Korpela, K., Tyrväinen, L., Tiittanen, P. and Lanki, T. 2019. Restorative effects of urban green environments and the role of urban-nature orientedness and noise sensitivity: A field experiment. *Health & Place*. **55**, pp.59–70.

Oliver, K., Kothari, A. and Mays, N. 2019. The dark side of coproduction: do the costs outweigh the benefits for health research? *Health Research Policy and Systems*. **17**(1), p.33.

Ordnance Survey (GB) 2020. *OS MasterMap Greenspace [SHAPE geospatial data],* [Online]. EDINA Digimap Ordnance Survey Service. [Accessed 7 July 2021]. Available from: https://digimap.edina.ac.uk.

Ordnance Survey Limited 2021a. *OS Open Green Space* [Online]. [Accessed 7 July 2021]. Available from: https://www.ordnancesurvey.co.uk/products/os-open-greenspace.

Ordnance Survey Limited 2021b. *OS Open Roads* [Online]. [Accessed 7 July 2021]. Available from: https://www.ordnancesurvey.co.uk/products/os-open-roads.

O'Sullivan, O.S., Holt, A.R., Warren, P.H. and Evans, K.L. 2017. Optimising UK urban road verge contributions to biodiversity and ecosystem services with cost-effective management. *Journal of Environmental Management*. **191**, pp.162–171.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. and Moher, D. 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. **372**, p.n71.

Panter, J., Mytton, O., Sharp, S., Brage, S., Cummins, S., Laverty, A.A., Wijndaele, K. and Ogilvie, D. 2018. Using alternatives to the car and risk of all-cause, cardiovascular and cancer mortality. *Heart*. **104**(21), pp.1749–1755.

Parmes, E., Pesce, G., Sabel, C.E., Baldacci, S., Bono, R., Brescianini, S., D'Ippolito, C., Hanke, W., Horvat, M., Liedes, H., Maio, S., Marchetti, P., Marcon, A., Medda, E., Molinier, M., Panunzi, S., Pärkkä, J., Polańska, K., Prud'homme, J., Ricci, P., Snoj Tratnik, J., Squillacioti, G., Stazi, M.A., Maesano, C.N. and Annesi-Maesano, I. 2020. Influence of residential land cover on childhood allergic and respiratory symptoms and diseases: Evidence from 9 European cohorts. *Environmental Research*. **183**, p.108953.

Parra, D.C., Van Zandt, A., Wang, P., Goodman, M., Abhishek, J., Haire-Joshu, D. and Brownson, R.C. 2019. Evaluating park use and satisfaction: The case of trojan park in St. Louis Missouri. *International Journal of Environmental Research and Public Health*. **16**(15).

Passmore, H.-A., Yang, Y. and Sabine, S. 2022. An Extended Replication Study of the Well-Being Intervention, the Noticing Nature Intervention (NNI). *Journal of Happiness Studies*. **23**(6), pp.2663–2683.

Paunović, K., Stansfeld, S., Clark, C. and Belojević, G. 2011. Epidemiological studies on noise and blood pressure in children: Observations and suggestions. *Environment International*. **37**(5), pp.1030–1041.

Pearson, A.L., Pfeiffer, K.A., Gardiner, J., Horton, T., Buxton, R.T., Hunter, R.F., Breeze, V. and McDade, T. 2020. Study of active neighborhoods in Detroit (StAND): Study protocol for a natural experiment evaluating the health benefits of ecological restoration of parks. *BMC Public Health*. **20**(1).

Pedersen, M., Giorgis-Allemand, L., Bernard, C., Aguilera, I., Andersen, A.-M.N., Ballester, F., Beelen, R.M.J., Chatzi, L., Cirach, M., Danileviciute, A., Dedele, A., Eijsden, M. van, Estarlich, M., Fernández-Somoano, A., Fernández, M.F., Forastiere, F., Gehring, U., Grazuleviciene, R., Gruzieva, O., Heude, B., Hoek, G., Hoogh, K. de, Hooven, E.H. van den, Håberg, S.E., Jaddoe, V.W.V., Klümper, C., Korek, M., Krämer, U., Lerchundi, A., Lepeule, J., Nafstad, P., Nystad, W., Patelarou, E., Porta, D., Postma, D., Raaschou-Nielsen, O., Rudnai, P., Sunyer, J., Stephanou, E., Sørensen, M., Thiering, E., Tuffnell, D., Varró, M.J., Vrijkotte, T.G.M., Wijga, A., Wilhelm, M., Wright, J., Nieuwenhuijsen, M.J., Pershagen, G., Brunekreef, B., Kogevinas, M. and Slama, R. 2013. Ambient air pollution and low birthweight: a European cohort study (ESCAPE). *The Lancet Respiratory Medicine*. **1**(9), pp.695–704.

Perchoux, C., Chaix, B., Brondeel, R. and Kestens, Y. 2016. Residential buffer, perceived neighborhood, and individual activity space: New refinements in the definition of exposure areas – The RECORD Cohort Study. *Health & Place*. **40**, pp.116–122.

Pereira, H.M., Ferrier, S., Walters, M., Geller, G.N., Jongman, R.H.G., Scholes, R.J., Bruford, M.W., Brummitt, N., Butchart, S.H.M., Cardoso, A.C., Coops, N.C., Dulloo, E., Faith, D.P., Freyhof, J., Gregory, R.D., Heip, C., Höft, R., Hurtt, G., Jetz, W., Karp, D.S., McGeoch, M.A., Obura, D., Onoda, Y., Pettorelli, N., Reyers, B., Sayre, R., Scharlemann, J.P.W., Stuart, S.N., Turak, E., Walpole, M. and Wegmann, M. 2013. Essential Biodiversity Variables. *Science*. **339**(6117), pp.277–278.

Pierce, J. and Lawhon, M. 2015. Walking as Method: Toward Methodological Forthrightness and Comparability in Urban Geographical Research. *The Professional Geographer*. **67**(4), pp.655–662.

Pilgrim, S.E., Cullen, L.C., Smith, D.J. and Pretty, J. 2008. Ecological Knowledge is Lost in Wealthier Communities and Countries. *Environmental Science & Technology*. **42**(4), pp.1004–1009.

Pink, S. 2007. Walking with video. *Visual Studies*. **22**(3), pp.240–252.

Plans, E., Gullón, P., Cebrecos, A., Fontán, M., Díez, J., Nieuwenhuijsen, M. and Franco, M. 2019. Density of Green Spaces and Cardiovascular Risk Factors in the City of Madrid: The Heart Healthy Hoods Study. *International Journal of Environmental Research and Public Health*. **16**(24).

Platt, L. 2012. “Parks Are Dangerous and the Sidewalk Is Closer”: Children’s Use of Neighborhood Space in Milwaukee, Wisconsin. *Children, Youth and Environments*. **22**, pp.194–213.

Plieninger, T., Kizos, T., Bieling, C., Le Dû-Blayo, L., Budniok, M.-A., Bürgi, M., Crumley, C.L., Girod, G., Howard, P., Kolen, J., Kuemmerle, T., Milcinski, G., Palang, H., Trommler, K. and Verburg, P.H. 2015. Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. *Ecology and Society*. **20**(2).

Pocock, M.J.O., Hamlin, I., Christelow, J., Passmore, HA. and Richardson, M. 2023. The benefits of citizen science and nature-noticing activities for well-being, nature connectedness and pro-nature conservation behaviours. *People and Nature*. **n/a**(n/a).

Pollard, E., Hall, M.L. and Bibby, C.J. 1986. *Monitoring the abundance of butterflies 1976–85*. Peterborough: Nature Conservancy Council.

Postles, M. and Bartlett, M. 2018. The rise of BioBlitz: Evaluating a popular event format for public engagement and wildlife recording in the United Kingdom. *Applied Environmental Education & Communication*. **17**(4), pp.365–379.

Potgieter, L.J., Gaertner, M., Kueffer, C., Larson, B.M.H., Livingstone, S.W., O'Farrell, P.J. and Richardson, D.M. 2017. Alien plants as mediators of ecosystem services and disservices in urban systems: a global review. *Biological Invasions*. **19**(12), pp.3571–3588.

Pregitzer, C.C., Ashton, M.S., Charlop-Powers, S., D'Amato, A.W., Frey, B.R., Gunther, B., Hallett, R.A., Pregitzer, K.S., Woodall, C.W. and Bradford, M.A. 2019. Defining and assessing urban forests to inform management and policy. *Environmental Research Letters*. **14**(8), p.085002.

Public Health England 2020. *Improving access to greenspace A new review for 2020* [Online]. London: Public Health England. [Accessed 13 September 2021]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904439/Improving_access_to_greenspace_2020_review.pdf.

Pyle, R.M. 2002. Eden in a vacant lot: special places, species, and kids in the neighborhood of life *In*: *Children and nature: psychological, sociocultural, and ecolutionary investigations*. MIT Press, pp.305–327.

Pyle, R.M. 1978. The extinction of experience. *Horticulture*. **56**(1), pp.64-67.

Qiu, L., Lindberg, S. and Nielsen, A.B. 2013. Is biodiversity attractive?—On-site perception of recreational and biodiversity values in urban green space. *Landscape and Urban Planning*. **119**, pp.136–146.

Rautio, N., Filatova, S., Lehtiniemi, H. and Miettunen, J. 2018. Living environment and its relationship to depressive mood: A systematic review. *International Journal of Social Psychiatry*. **64**(1), pp.92–103.

Reed, J.A., Arant, C.-A., Wells, P., Stevens, K., Hagen, S. and Harring, H. 2008. A descriptive examination of the most frequently used activity settings in 25 community parks using direct observation. *Journal of Physical Activity and Health*. **5**(SUPPL. 1), pp.S183–S195.

Reed, J.A. and Hooker, S.P. 2012. Where are youth physically active? A descriptive examination of 45 parks in a southeastern community. *Childhood Obesity*. **8**(2), pp.124–131.

Reed, J.A., Morrison, A. and Arant, C.-A. 2009. Profile differences of users of paved versus natural-surface trails. *Journal of Physical Activity and Health*. **6**(1), pp.112–118.

Richardson, M., Passmore, H.-A., Lumber, R., Thomas, R. and Hunt, A. 2021. Moments, not minutes: The nature-wellbeing relationship. *International Journal of Wellbeing*. **11**(1).

Richardson, M. and Sheffield, D. 2017. Three good things in nature: noticing nearby nature brings sustained increases in connection with nature / Tres cosas buenas de la naturaleza: prestar atención a la naturaleza cercana produce incrementos prolongados en conexión con la naturaleza. *PsyEcology*. **8**(1), pp.1–32.

Rigolon, A. 2016. A complex landscape of inequity in access to urban parks: A literature review. *Landscape and Urban Planning*. **153**, pp.160–169.

Roberts, H., van Lissa, C., Hagedoorn, P., Kellar, I. and Helbich, M. 2019. The effect of short-term exposure to the natural environment on depressive mood: A systematic review and meta-analysis. *Environmental Research*. **177**, p.108606.

Roberts, H., McEachan, R., Margary, T., Conner, M. and Kellar, I. 2018. Identifying Effective Behavior Change Techniques in Built Environment Interventions to Increase Use of Green Space: A Systematic Review. *Environment and Behavior*. **50**(1), pp.28–55.

Robinson, J.M., Mavoa, S., Robinson, K. and Brindley, P. 2022. Urban centre green metrics in Great Britain: A geospatial and socioecological study. *PLOS ONE*. **17**(11), p.e0276962.

Rojas-Rueda, D., Nazelle, A. de, Andersen, Z.J., Braun-Fahrländer, C., Bruha, J., Bruhova-Foltynova, H., Desqueyroux, H., Praznoczy, C., Ragettli, M.S., Tainio, M. and Nieuwenhuijsen, M.J. 2016. Health Impacts of Active Transportation in Europe. *PLOS ONE*. **11**(3), p.e0149990.

Rojas-Rueda, D., Nieuwenhuijsen, M.J., Gascon, M., Perez-Leon, D. and Mudu, P. 2019. Green spaces and mortality: a systematic review and meta-analysis of cohort studies. *The Lancet Planetary Health*. **3**(11), pp.e469–e477.

Rojas-Rueda, D., Vaught, E. and Buss, D. 2021. Why a New Research Agenda on Green Spaces and Health Is Needed in Latin America: Results of a Systematic Review. *International Journal of Environmental Research and Public Health*. **18**(11), p.5839.

Rook, G. a. W. 2010. 99th Dahlem conference on infection, inflammation and chronic inflammatory disorders: darwinian medicine and the ‘hygiene’ or ‘old friends’ hypothesis. *Clinical and Experimental Immunology*. **160**(1), pp.70–79.

Roux, A.V., Evenson, K.R., McGinn, A.P., Laatitia, D.G., Brines, S. and Jacobs, D.R. 2007. Density of recreational resources and physical activity in a sample of adults. *Am. J. Public Health*. **55**(1), p.493.

Royer, H., Yengue, J.L. and Bech, N. 2023. Urban agriculture and its biodiversity: What is it and what lives in it? *Agriculture, Ecosystems & Environment*. **346**, p.108342.

Ruokolainen, L., von Hertzen, L., Fyhrquist, N., Laatikainen, T., Lehtomäki, J., Auvinen, P., Karvonen, A.M., Hyvärinen, A., Tillmann, V., Niemelä, O., Knip, M., Haahtela, T., Pekkanen, J. and Hanski, I. 2015. Green areas around homes reduce atopic sensitization in children. *Allergy*. **70**(2), pp.195–202.

Rupprecht, C.D.D. and Byrne, J.A. 2014. Informal urban greenspace: A typology and trilingual systematic review of its role for urban residents and trends in the literature. *Urban Forestry & Urban Greening*. **13**(4), pp.597–611.

Rydin, Y., Bleahu, A., Davies, M., Dávila, J.D., Friel, S., Grandis, G.D., Groce, N., Hallal, P.C., Hamilton, I., Howden-Chapman, P., Lai, K.-M., Lim, C.J., Martins, J., Osrin, D., Ridley, I., Scott, I., Taylor, M., Wilkinson, P. and Wilson, J. 2012. Shaping cities for health: complexity and the planning of urban environments in the 21st century. *The Lancet*. **379**(9831), pp.2079–2108.

Saarinen, K., Valtonen, A., Jantunen, J. and Saarnio, S. 2005. Butterflies and diurnal moths along road verges: Does road type affect diversity and abundance? *Biological Conservation*. **123**(3), pp.403–412.

Sami, M., Smith, M. and Ogunseitan, O.A. 2020. Placement of outdoor exercise equipment and physical activity: A quasi-experimental study in two parks in Southern California. *International Journal of Environmental Research and Public Health*. **17**(7).

Samuelson, A.E., Gill, R.J., Brown, M.J.F. and Leadbeater, E. 2018. Lower bumblebee colony reproductive success in agricultural compared with urban environments. *Proceedings of the Royal Society B: Biological Sciences*. **285**(1881), p.20180807.

Sandifer, P.A., Sutton-Grier, A.E. and Ward, B.P. 2015. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services*. **12**, pp.1–15.

Saunders, L. 2022. Healthy Streets Tool. *Healthy Streets*. [Online]. [Accessed 8 October 2022]. Available from: https://www.healthystreets.com/resources.

Schroeder, H.W. 1982. Preferred features of urban parks and forests. *Journal of Arboricuture 8(12):317-322*. **8**(12).

Schroeder, H.W. and Anderson, L.M. 1984. Perception of Personal Safety in Urban Recreation Sites. *Journal of Leisure Research*. **16**(2), pp.178–194.

Schultz, W.P. 2001. The Structure of Environmental Concern: Concern for Self, Other People, and the Biosphere. *Journal of Environmental Psychology*. **21**(4), pp.327–339.

Scott, A., Carter, C., Brown, K. and White, V. 2009. 'Seeing is Not Everything': Exploring the Landscape Experiences of Different Publics. *Landscape Research*. **34**(4), pp.397–424.

Seaman, P.J., Jones, R. and Ellaway, A. 2010. It's not just about the park, it's about integration too: why people choose to use or not use urban greenspaces. *The International Journal of Behavioral Nutrition and Physical Activity*. **7**, p.78.

Secretariat of the Convention on Biological Diversity 2006. Convention Text. Article 2. Use of Terms.

Seiwert, A. and Rößler, S. 2020. Understanding the term green infrastructure: origins, rationales, semantic content and purposes as well as its relevance for application in spatial planning. *Land Use Policy*. **97**, p.104785.

Selway, C.A., Mills, J.G., Weinstein, P., Skelly, C., Yadav, S., Lowe, A., Breed, M.F. and Weyrich, L.S. 2020. Transfer of environmental microbes to the skin and respiratory tract of humans after urban green space exposure. *Environment International*. **145**, p.106084.

Seto, K.C., Fragkias, M., Güneralp, B. and Reilly, M.K. 2011. A Meta-Analysis of Global Urban Land Expansion. *PLOS ONE*. **6**(8), p.e23777.

Shah, N., Cader, M., Andrews, B., McCabe, R. and Stewart-Brown, S.L. 2021. Short Warwick-Edinburgh Mental Well-being Scale (SWEMWBS): performance in a clinical sample in relation to PHQ-9 and GAD-7. *Health and Quality of Life Outcomes*. **19**(1), p.260.

Shanahan, D.F., Bush, R., Gaston, K.J., Lin, B.B., Dean, J., Barber, E. and Fuller, R.A. 2016. Health Benefits from Nature Experiences Depend on Dose. *Scientific Reports*. **6**(1), p.28551.

Shores, K.A. and West, S.T. 2010. Rural and urban park visits and park-based physical activity. *Preventive Medicine*. **50**(SUPPL.), pp.S13–S17.

Shores, K.A. and West, S.T. 2008. The relationship between built park environments and physical activity in four park locations. *Journal of Public Health Management and Practice*. **14**(3), pp.e9–e16.

Skeenaghan 2020. systmOne. *TPP*. [Online]. [Accessed 21 October 2022]. Available from: https://tpp-uk.com/products/.

Soga, M. and Gaston, K.J. 2018. Shifting baseline syndrome: causes, consequences, and implications. *Frontiers in Ecology and the Environment*. **16**(4), pp.222–230.

Soltanifard, H. and Jafari, E. 2019. A conceptual framework to assess ecological quality of urban green space: a case study in Mashhad city, Iran. *Environment, Development and Sustainability*. **21**(4), pp.1781–1808.

Southon, G.E., Jorgensen, A., Dunnett, N., Hoyle, H. and Evans, K.L. 2017. Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. *Landscape and Urban Planning*. **158**, pp.105–118.

Southon, G.E., Jorgensen, A., Dunnett, N., Hoyle, H. and Evans, K.L. 2018. Perceived species-richness in urban green spaces: Cues, accuracy and well-being impacts. *Landscape and Urban Planning*. **172**, pp.1–10.

Spitzer, R.L., Kroenke, K., Williams, J.B.W. and Löwe, B. 2006. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Archives of Internal Medicine*. **166**(10), pp.1092–1097.

Sreetheran, M. and van den Bosch, C.C.K. 2014. A socio-ecological exploration of fear of crime in urban green spaces – A systematic review. *Urban Forestry & Urban Greening*. **13**(1), pp.1–18.

Stewart-Brown, S., Tennant, A., Tennant, R., Platt, S., Parkinson, J. and Weich, S. 2009. Internal construct validity of the Warwick-Edinburgh Mental Well-being Scale (WEMWBS): a Rasch analysis using data from the Scottish Health Education Population Survey. *Health and Quality of Life Outcomes*. **7**(1), p.15.

Sullivan, W.C., Kuo, F.E. and DePooter, S.F. 2004. The fruit of urban nature: Vital neighborhood spaces. *Environment and Behavior*. **36**(5), pp.678–700.

Sutherland, W.J., Shackelford, G. and Rose, D.C. 2017. Collaborating with communities: co-production or co-assessment? *Oryx*. **51**(4), pp.569–570.

Tallis, M., Taylor, G., Sinnett, D. and Freer-Smith, P. 2011. Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*. **103**(2), pp.129–138.

Taylor, A.F., Kuo, F.E. and Sullivan, W.C. 2002. Views of Nature and Self-Discipline: Evidence from Inner City Children. *Journal of Environmental Psychology*. **22**(1), pp.49–63.

Taylor, L. and Hochuli, D.F. 2017. Defining greenspace: Multiple uses across multiple disciplines. *Landscape and Urban Planning*. **158**, pp.25–38.

Tennant, R., Hiller, L., Fishwick, R., Platt, S., Joseph, S., Weich, S., Parkinson, J., Secker, J. and Stewart-Brown, S. 2007. The Warwick-Edinburgh Mental Well-being Scale (WEMWBS): development and UK validation. *Health and Quality of Life Outcomes*. **5**(1), p.63.

Tester, J. and Baker, R. 2009. Making the playfields even: Evaluating the impact of an environmental intervention on park use and physical activity. *Preventive Medicine*. **48**(4), pp.316–320.

The Council of Europe 2004. European Landscape Convention, Florence Convention.

The Office for National Statistics, ONS 2021. National life tables – life expectancy in the UK - Office for National Statistics. [Accessed 21 October 2022]. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/bulletins/nationallifetablesunitedkingdom/2018to2020.

Thomas, R., Lello, J., Medeiros, R., Pollard, A., Robinson, P., Seward, A., Smith, J., Vafidis, J. and Vaughan, I. 2017. *Data Analysis with R statistical Software: A Guidebook for Scientists*. Eco-Explore CIC.

Thompson, C.W., Aspinall, P. and Montarzino, A. 2008. The Childhood Factor: Adult Visits to Green Places and the Significance of Childhood Experience. *Environment and Behavior*. **40**(1), pp.111–143.

Tillmann, S., Tobin, D., Avison, W. and Gilliland, J. 2018. Mental health benefits of interactions with nature in children and teenagers: a systematic review. *J Epidemiol Community Health*. **72**(10), pp.958–966.

Tischer, C., Gascon, M., Fernández-Somoano, A., Tardón, A., Lertxundi Materola, A., Ibarluzea, J., Ferrero, A., Estarlich, M., Cirach, M., Vrijheid, M., Fuertes, E., Dalmau-Bueno, A., Nieuwenhuijsen, M.J., Antó, J.M., Sunyer, J. and Dadvand, P. 2017. Urban green and grey space in relation to respiratory health in children. *The European Respiratory Journal*. **49**(6), p.1502112.

Turkseven Dogrusoy, I. and Zengel, R. 2017. Analysis of Perceived Safety in Urban Parks: A Field Study In Büyükpark And Hasanağa Park. *METU Journal of the Faculty of Architecture*. **34**.

Twohig-Bennett, C. and Jones, A. 2018. The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research*. **166**, pp.628–637.

UKCEH 2023. UK Pollinator Monitoring Scheme (PoMS). [Accessed 14 April 2023]. Available from: https://ukpoms.org.uk/.

Ulrich, R. 1984. View Through a Window May Influence Recovery from Surgery. *Science (New York, N.Y.)*. **224**, pp.420–1.

United Nations 2022. Sustainable Development Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable. Goal 11 | Department of Economic and Social Affairs https://sustainabledevelopment.un.org/sdg11. 2019. [Accessed 13 February 2023]. Available from: https://sdgs.un.org/goals/goal11.

United Nations Human Settlements Programme 2022. *World Cities Report 2022: Envisaging the Future of Cities* [Online]. Nairobi, Kenya: United Nations Human Settlements Programme (UN-Habitat). [Accessed 16 February 2023]. Available from: https://unhabitat.org/wcr/.

Van den Berg, A.E. and Koole, S.L. 2006. New wilderness in the Netherlands: An investigation of visual preferences for nature development landscapes. *Landscape and Urban Planning*. **78**(4), pp.362–372.

Van Hecke, L., Van Cauwenberg, J., Clarys, P., Van Dyck, D., Veitch, J. and Deforche, B. 2017. Active use of parks in flanders (Belgium): An exploratory observational study. *International Journal of Environmental Research and Public Health*. **14**(1).

Voghera, A. and Giudice, B. 2019. Evaluating and Planning Green Infrastructure: A Strategic Perspective for Sustainability and Resilience. *Sustainability*. **11**(10), p.2726.

Wang, R., Zhao, J., Meitner, M.J., Hu, Y. and Xu, X. 2019. Characteristics of urban green spaces in relation to aesthetic preference and stress recovery. *Urban Forestry & Urban Greening*. **41**, pp.6–13.

Warembourg, C., Maitre, L., Tamayo-Uria, I., Fossati, S., Roumeliotaki, T., Aasvang, G.M., Andrusaityte, S., Casas, M., Cequier, E., Chatzi, L., Dedele, A., Gonzalez, J.-R., Gražulevičienė, R., Haug, L.S., Hernandez-Ferrer, C., Heude, B., Karachaliou, M., Krog, N.H., McEachan, R., Nieuwenhuijsen, M., Petraviciene, I., Quentin, J., Robinson, O., Sakhi, A.K., Slama, R., Thomsen, C., Urquiza, J., Vafeiadi, M., West, J., Wright, J., Vrijheid, M. and Basagaña, X. 2019. Early-Life Environmental Exposures and Blood Pressure in Children. *Journal of the American College of Cardiology*. **74**(10), pp.1317–1328.

Warembourg, C., Nieuwenhuijsen, M., Ballester, F., de Castro, M., Chatzi, L., Esplugues, A., Heude, B., Maitre, L., McEachan, R., Robinson, O., Slama, R., Sunyer, J., Urquiza, J., Wright, J., Basagaña, X. and Vrijheid, M. 2021. Urban environment during early-life and blood pressure in young children. *Environment International*. **146**, p.106174.

Weber, F., Kowarik, I. and Säumel, I. 2014. A walk on the wild side: Perceptions of roadside vegetation beyond trees. *Urban Forestry & Urban Greening*. **13**(2), pp.205–212.

Wells, N.M. and Lekies, K.S. 2006. Nature and the Life Course: Pathways from Childhood Nature Experiences to Adult Environmentalism. *Children, Youth and Environments*. **16**(1), pp.1–24.

WEMWBS 2011. wemwbs_population_norms_in_health_survey_for_england_data_2011.pdf. [Accessed 2 August 2022]. Available from: https://warwick.ac.uk/fac/sci/med/research/platform/wemwbs/using/howto/wemwbs_population_norms_in_health_survey_for_england_data_2011.pdf.

Wheeler, B.W., Lovell, R., Higgins, S.L., White, M.P., Alcock, I., Osborne, N.J., Husk, K., Sabel, C.E. and Depledge, M.H. 2015. Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality. *International Journal of Health Geographics*. **14**(1), p.17.

White, M.P., Alcock, I., Grellier, J., Wheeler, B.W., Hartig, T., Warber, S.L., Bone, A., Depledge, M.H. and Fleming, L.E. 2019. Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Scientific Reports*. **9**(1), p.7730.

White, M.P., Alcock, I., Wheeler, B.W. and Depledge, M.H. 2013. Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. *Psychological Science*. **24**(6), pp.920–928.

White, M.P., Elliott, L.R., Gascon, M., Roberts, B. and Fleming, L.E. 2020. Blue space, health and well-being: A narrative overview and synthesis of potential benefits. *Environmental Research*. **191**, p.110169.

Whitebread, D. 2017. Free play and children's mental health. *The Lancet Child & Adolescent Health*. **1**(3), pp.167–169.

Williamson, P.R., Altman, D.G., Blazeby, J.M., Clarke, M., Devane, D., Gargon, E. and Tugwell, P. 2012. Developing core outcome sets for clinical trials: issues to consider. *Trials*. **13**(1), p.132.

Wilson, G.L. and Kelling, J.Q. 1982. Broken Windows. *The Atlantic*. [Online]. [Accessed 12 May 2023]. Available from: https://www.theatlantic.com/magazine/archive/1982/03/broken-windows/304465/.

Wojciechowska, B., Pełka, J., Korzon, L., Kozłowska, A., Kaczała, M., Jarzebska, M., Gwardys, T. and Kowalski, M.L. 2007. Prevalence of allergy, patterns of allergic sensitization and allergy risk factors in rural and urban children. *Allergy*. **62**(9), pp.1044–1050.

Wood, E., Harsant, A., Dallimer, M., Cronin de Chavez, A., McEachan, R.R.C. and Hassall, C. 2018. Not All Green Space Is Created Equal: Biodiversity Predicts Psychological Restorative Benefits From Urban Green Space. *Frontiers in Psychology*. **9**.

World Health Organisation 2022. *WHO European Regional Obesity Report 2022* [Online]. WHO Regional Office for Europe Copenhagen. [Accessed 16 February 2023]. Available from: https://apps.who.int/iris/bitstream/handle/10665/353747/9789289057738-eng.pdf.

World Health Organization 2023a. Constitution of the World Health Organization. [Accessed 16 March 2023]. Available from: https://www.who.int/about/governance/constitution.

World Health Organization 2023b. Mental health. [Accessed 16 March 2023]. Available from: https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response.

World Health Organization 2017. *Urban green space interventions and health: A review of impacts and effectiveness. Full report* [Online]. World Health Organization, Regional Office for Europe. [Accessed 5 May 2023]. Available from: https://www.who.int/europe/publications/m/item/urban-green-space-interventions-and-health--a-review-of-impacts-and-effectiveness.-full-report.

World Health Organization 2016. *Urban green spaces and health* [Online]. World Health Organization. Regional Office for Europe. [Accessed 3 May 2023]. Available from: https://apps.who.int/iris/handle/10665/345751.

World Health Organization 2008. *WHO Commission on Social Determinants of Health. Closing the gap in a generation: health equity through action on the social determinants of health: commission on social determinants of health final report.* [Online]. Geneva. [Accessed 3 November 2023]. Available from: https://www.who.int/publications/i/item/WHO-IER-CSDH-08.1.

Wright, J., Small, N., Raynor, P., Tuffnell, D., Bhopal, R., Cameron, N., Fairley, L., Lawlor, D.A., Parslow, R., Petherick, E.S., Pickett, K.E., Waiblinger, D., West, J., and on behalf of the Born in Bradford Scientific Collaborators Group 2013. Cohort Profile: The Born in Bradford multi-ethnic family cohort study. *International Journal of Epidemiology*. **42**(4), pp.978–991.

Wyles, K.J., White, M.P., Hattam, C., Pahl, S., King, H. and Austen, M. 2019. Are Some Natural Environments More Psychologically Beneficial Than Others? The Importance of Type and Quality on Connectedness to Nature and Psychological Restoration. *Environment and Behavior*. **51**(2), pp.111–143.

Wylie, J. 2005. A single day's walking: narrating self and landscape on the South West Coast Path. *Transactions of the Institute of British Geographers*. **30**(2), pp.234–247.

Yang, B.-Y., Markevych, I., Bloom, M.S., Heinrich, J., Guo, Y., Morawska, L., Dharmage, S.C., Knibbs, L.D., Jalaludin, B., Jalava, P., Zeng, X.-W., Hu, L.-W., Liu, K.-K. and Dong, G.-H. 2019. Community greenness, blood pressure, and hypertension in urban dwellers: The 33 Communities Chinese Health Study. *Environment International*. **126**, pp.727–734.

Yao, L., Liu, J., Wang, R., Yin, K. and Han, B. 2014. Effective green equivalent—A measure of public green spaces for cities. *Ecological Indicators*. **47**, pp.123–127.

Young, J.C., Waylen, K.A., Sarkki, S., Albon, S., Bainbridge, I., Balian, E., Davidson, J., Edwards, D., Fairley, R., Margerison, C., McCracken, D., Owen, R., Quine, C.P., Stewart-Roper, C., Thompson, D., Tinch, R., Van den Hove, S. and Watt, A. 2014. Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. *Biodiversity and Conservation*. **23**(2), pp.387–404.

Zednik, K. and Pali-Schöll, I. 2022. One Health: areas in the living environment of people and animals and their effects on allergy and asthma. *Allergo Journal International*. **31**(4), pp.103–113.