The Nature of Health: Understanding the nuanced relationship between biodiversity and human wellbeing

by

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Abbreviations

Abbreviation	Meaning
μS	microSiemens,
ABC	Australian Broadcasting Commission
ABS	Australian Bureau of Statistics
ADHD	Attention Deficit Hyperactivity Disorder
AIC	Akaike Information Criterion
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ART	Attention Restoration Theory
BEI	Biodiversity Experience Index
BIC	Bayesian Information Criterion
BPM	Beats per minute
BRAT-DO	Bedimo-Rung Assessment Tool – Direct Observation
CPAT	Community Park Audit Tool
EAPRS	Environmental Assessment of Public Recreation Spaces
EDA	Electrodermal Activity
EEG	Electroencephalography
HMD	Head mounted display
HR	Heart rate
Hz	Hertz
IVE	Immersive Virtual Environment
Km	Kilometer
LGA	Local Government Area
LGASA	Local Government Association of South Australia

m	Meter
MEA	Millennium Ecosystem Assessment
NRPA	National Recreation and Parks Association
NRS	Nature Relatedness Scale
PARA	Physical Activity Resource Assessment Tool
POST	Public Open Space Tool
PPGIS	Public Participation Geographic Information System
PSS	Perceived Stress Scale
PRS	Perceived Restorativeness Scale
SA	South Australia
SPSS	Statistical Package for Social Sciences®
SRT	Psycho-Evolutionary Stress Reduction Theory
T1	First time point
TSST	Trier Social Stress Test
TSST-IVE	Immersive Virtual Environment version of the TSST
UK	United Kingdom
UPNI	Urban Park Naturalness Index
USDA	United States Department of Agriculture
VAS	Visual Analog Scale
VIF	Variance Inflation Factor
VR	Virtual Reality
qEEG	Quantitative Electroencephalography
WHO	World Health Organization

Glossary

Term	Meaning
Affect	The experience of feeling or emotion
Anthropic elements	Items within a park setting that are included purely for the benefit of people. For example, seating, picnic shelters, playgrounds or sculptures.
Attention Restoration Theory	One of two dominant theories explaining the restoration one experiences in certain environments. The theory was developed by Kaplan and Kaplan (1989) and focuses on recovery from cognitive and attentional fatigue.
Benefits	Changes that are considered advantageous to an individual, group or community (Driver, 2002)
Biodiversity	The variety of plant and animal species. Biodiversity may be evaluated on a global or local basis with higher levels considered more desirable, and indeed essential, than lower levels to achieve many ecosystem services.
Biophilia	An innate tendency to seek connections with nature and other forms of life
Compatibility	A characteristic that according to the attention restoration theory is important in facilitating restoration. It refers to the ability of a landscape to facilitate the intentions or needs of a person.
Council	Local Government Area (used interchangeably in this thesis)
Ecological Literacy	The ability of individuals to understand the natural systems that make life on Earth possible.
Ecosystem services	The diverse benefits that humans gain from natural environments and properly functioning ecosystems.

Empatica E4	Wristband for recording physiological data
Environmental generational amnesia	The idea that each generation can only recognize—and appreciate—the ecological changes they experience in their lifetime
Extent	A characteristic that according to the attention restoration theory is important in facilitating restoration. It refers to the ability of a landscape to facilitate an immersive experience.
Fascination	A characteristic that according to the attention restoration theory is important in facilitating restoration. It refers to the ability of a landscape to catch attention without cognitive effort.
Favorite Places	Physical locations that individuals have formed and emotional tie or effective bond with (Korpela et al. 2009)
Green space	Areas of parks, gardens, forests, grass, trees or protected areas set aside for recreation, aesthetic purposes, and/or conservation purposes, as distinct from built environments or blue space (oceans).
Habitat diversity	Measure of the broad habitat types in an area. In the context of this thesis, only those habitat types occupying at least $100m^2$ were included.
Hertz	Measure of frequency, one cycle per second
microSiemens	A measure of electrical conductivity
Naturalness	The perception of a space as natural. In the context of this thesis, it is differentiated from the term biodiversity.
Nature-relatedness	The extent to which people consider nature as part of their identity, typically measured using the Nature Relatedness Scale

Perceptions	The way a person interprets or understands stimuli or concepts.
Place attachment	The affective bonds that develop between an individual and a geographic locale
Planar Elements	Elements that can be mapped on in two-dimensional format, for example vegetation coverage.
Presence	The feeling of being in the virtual world and not in the real world
Restorative environments	Physical environments that facilitate health benefits.
Sacrificial Management	An indirect park management technique based on the concept that some areas are inherently more valuable than others and as such planning and management strategies concentrate use into some spaces (sacrificial areas) that are usually resilient or of less conservation value and distribute use away from areas that are more ecologically fragile.
Savanna	An ecosystem characterised by an herbaceous layer consisting primarily of grasses, and widely spaced trees (open canopy) found in in tropical and subtropical areas. In the context of this thesis it is used in reference to evolutionary theory that suggests people have an innate preference for this landscape type.
Species richness	The number of different species (e.g. plants and animals) represented in a specific area (e.g. a park, ecological community, landscape or region).
Stress Reduction Theory	One of two dominant theories explaining the restoration one experiences in certain environments. The theory was developed by Ulrich (1983) and focuses on recovery from stress.

Structural heterogeneity	Measure of vertical distribution of ecosystem components within a park, for example, variation in plant heights and life stages, potential micro-habitats and topographical features.
Urban parks	A park located within a developed landscape, for example a city, rather than a rural or remote area.
Wellbeing	A state of wellness that suggests positive appraisal of physical and/or mental health. The use of the term in this thesis is aligned with the concept of health.

Abstract

Biodiversity is vital for our survival, and yet on a global scale, it is irrevocably and undeniably diminishing at an alarming rate. Connecting people with the biological world is a significant challenge, given our increasingly urbanised and indoor worlds. However, this thesis argues that fostering such a connection is crucial and relies on a greater understanding of the relationship between biodiversity and human wellbeing in urban green space. As such, this pragmatic research centres around four broad objectives: 1. determining the ecological attributes people value in their favorite environments and the relative importance placed on those attributes in the context of restorative experiences; 2. comparing people's perceptions of biodiversity to objective measures of the environment; 3. examining the relationship between biodiversity, human perceptions, and the wellbeing benefits people derive from urban green space; and 4. investigating whether there is a causal relationship between biodiversity and wellbeing outcomes. Sequentially, these objectives begin to build a more nuanced understanding of how we can balance the health of nature and the health of people in urban areas. Using a combination of research techniques, including online surveys, mail-back surveys, site assessments and virtual reality, a detailed understanding of the relationship between biodiversity and human heath was developed. As exemplars of restorative environments, favorite places were found to be strongly associated with "fascination". Micro-variables such as birds, plants, wildlife, native species, and biodiversity were also strongly associated with these places. A gap between people's perceptions of biodiversity and actual biodiversity was noted, however, vegetation cover, habitat diversity and a proposed Urban Park Naturalness Index were determined to be the strongest predictors of biodiversity perceptions, explaining 31% of respondent's perceptions. Interestingly, subtle changes in assessed attributes significantly affected predicted biodiversity perceptions, with every additional habitat type within a park increasing the probability of the park being in a higher perceived biodiversity category by 32%. Perceived, rather than objective measures of biodiversity were better predictors of wellbeing benefits. Vegetation cover correlated most strongly with psychological benefits. Stress reduction and mood improvement were greatest in nature parks and lowest in pocket parks. Increases in each biodiversity attribute significantly affected psychological wellbeing at different thresholds, suggesting the relationship between biodiversity and wellbeing is not linear. The results from the final

immersive Virtual Reality study also suggested that the relationship between biodiversity and wellbeing is not linear. Stress recovery was less effective in urban than natural environments, but the greatest improvement in most wellbeing measures was associated with the low biodiversity environment. This is consistent with evolutionary theory that suggests an innate human preference for savanna-like landscapes. The thesis discusses practical recommendations for planners and park managers as well as theoretical challenges for future researchers. It concludes with a conviction that the attainment of sustainable socio-ecological systems, in which biodiversity and human wellbeing are balanced, is both possible and essential.

Declaration

This thesis presents work carried out by myself and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, are clearly acknowledged.

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List of Outputs

Throughout the course of this PhD, there have been various outputs, including peer-reviewed journal articles, conference presentations, awards, and an industry report. Some of these outputs contribute strongly to this thesis, for example, the journal publications form chapters 4-6. The awards, conference presentations, and industry reports have contributed to the overall PhD program, but do not form any part of the thesis.

Journal Publications

Chapter 3:

- Schebella, M. F., Weber, D., Lindsey, K. and Daniels, C. (2017). For the love of nature: Exploring the importance of species diversity and micro-variables associated with favorite outdoor places. *Frontiers in Psychology*, 8, 1-21.doi:10.3389/fpsyg.2017.02094

Chapter 4:

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Chapter 5:

- Schebella, M. F., Weber, D., Schultz, L. and Weinstein, P. (2018). The nature of health: a comparison of the wellbeing benefits associated with perceived and estimated biodiversity in Australian urban green spaces. Under review in: *Sustainability*.

Chapter 6:

- Schebella, M. F., Weber, D., Schultz, L. and Kor, M. (2018). The nature of reality: human stress recovery during exposure to biodiverse, multi-sensory virtual environments. Under review in: *International Journal of Environmental Research and Public Health*.

Industry Reports

- Schebella, M. F., Weber, D., Brown, G. and Hatton MacDonald, D. (2014). The importance of irrigated urban green space: health and recreational benefits perspectives. Goyder Industry for Water Research Technical Report Series No. 14/2, Adelaide, South Australia.

Conferences

- Schebella, M. F., Gaut, A. and Weber, D. *The Nature of Health*. Australian Positive Psychology and Wellbeing Conference (2016)
- Schebella, M.F. *Balancing ecology and psychology in urban green space*. Natural and Built Environments Research Centre Colloquium (2017)

Awards

- Vice Chancellor and Presidents Scholarship, University of South Australia
- Australian Postgraduate Award, Australian Federal Government
- Images of Research Competition, University of South Australia

Related journal publications not included in this thesis

- Brown, G., Schebella, M. F., Weber, D. (2014). Using participatory GIS to measure physical activity and urban park benefits. *Landscape and Urban Planning* 121, 34-44.

Author Contributions

Co-author contributions to the published works presented in this thesis.

Chapter	Name	Contribution
3	Morgan Schebella	• Developed research questions and administered questionnaire • Determined approach to analysis • Analyzed the results • Wrote multiple iterations of the manuscript • Revised the manuscript and responded to peer-review
	Delene Weber	• Assisted in development of research questions • Assisted in triangulation of content analysis • Reviewed draft manuscript and provided feedback
	Kiera Lindsey	• Promoted study • Reviewed draft manuscript
	Christopher Daniels	• Promoted study • Reviewed draft manuscript
4	Morgan Schebella	• Developed assessment tools • Conducted on-site assessments • Designed and conducted the pilot study • Designed and administered the questionnaire • Analyzed the full dataset • Wrote multiple iterations of the manuscript • Revised the manuscript and responded to peer-review
	Delene Weber	• Assisted in developing research questions • Assisted in developing questionnaire • Reviewed draft manuscript and provided feedback
	Philip Weinstein	• Assisted in developing research questions • Reviewed draft manuscript and provided feedback
	Lisa Schultz	• Advised on appropriate approach to analysis • Reviewed results and provided feedback on analysis • Reviewed draft manuscript and provided feedback
5	Morgan Schebella	• Designed and administered the questionnaire • Analyzed the full dataset • Wrote multiple iterations of the manuscript • Revised the manuscript and responded to peer-review
	Delene Weber	• Assisted in developing research questions • Assisted in developing questionnaire • Reviewed draft manuscript and provided feedback • Assisted in responding to peer-review
	Lisa Schultz	• Advised on appropriate approach to analysis • Reviewed results and provided feedback on analysis • Reviewed draft manuscript and provided feedback
	Philip Weinstein	• Assisted in developing research questions • Reviewed draft manuscript and provided feedback
6	Morgan Schebella	• Devised and developed the TSST-IVE • Filmed IVE scenes • Developed research questions and measures • Recruited participants • Conducted the experiment • Analyzed the data • Wrote multiple iterations of the manuscript
	Delene Weber	• Assisted in developing research questions • Assisted in developing questionnaire • Reviewed draft manuscript and provided feedback
	Lisa Schultz	• Advised on appropriate approach to analysis • Reviewed draft manuscript and provided feedback
	Philip Weinstein	• Assisted in developing research questions • Reviewed draft manuscript and provided feedback

Chapter 1. Introduction

If we hope to stem the tide of environmental degradation and biodiversity loss that is rapidly flooding the planet, then we should turn our attention to the managed landscape, to the places where we live, work, and play. We should not assume that nature, if left alone, will take care of itself. Rather, if we want the environment to be a certain way, we must actively manage for the conditions we desire. People must be part of the equation.

Robertson and Hull (2001)

Modo liceat vivere, est spes

While there's life, there's hope

Publius Terentius Afer

1.1. Introduction to the problem

Life on Earth is striking in its complexity. Its very diversity is its most extraordinary feature (Tilman, 2000), without which, many of the ecosystem goods and services that underpin our existence would be lost (Cardinale et al., 2012). Yet, on a global scale, biodiversity is irrevocably and undeniably diminishing at an unprecedented rate (De Vos et al., 2015). The drivers of this decline are many, amongst them a rapidly growing and increasingly urbanized human population (Crist et al., 2017). The exodus of people from rural areas to ever-expanding cities over the past few decades has not only caused substantial deterioration to some of the world's most diverse ecosystems and biodiversity hotspots (Cincotta et al., 2000), but has also seen a momentous shift in the way human beings interact with the living world. The effects of this shift are being felt in many ways: physically, emotionally, and cognitively, societies are becoming disconnected from the biological world (Kesebir and Kesebir, 2017); public awareness and understanding of ecological concepts is declining (Lindemann-Matthies and Bose, 2008, Thompson et al., 2016); and ultimately, despite an extensive body of work highlighting the links between

nature and human wellbeing, it remains difficult to connect the consequences of ecological loss to the everyday experience of urban people (McDonald et al., 2015). In part, this is because as scientists and conservationists, we have "failed to convey the importance, wonder and relevance of biodiversity to the general public" (Miller, 2005, p. 430). This research seeks to examine the nuanced relationship between biodiversity and the wellbeing benefits that are derived from nature experiences in urban areas, i.e. the places where we live, work, and play. In doing so, this research hopes to further our understanding of how we might attain sustainable socio-ecological systems, in which biodiversity and human wellbeing are balanced, even in cities. In this chapter, I provide a brief introduction to the problem and the key research gaps addressed by this thesis.

1.1.1. Urban nature and human wellbeing

The environment, whether natural or built, has the ability to shape the health and wellbeing of populations (Beil and Hanes, 2013, Guite et al., 2006, Evans, 2003). Research reveals that a key element of healthy urban living environments is the presence of green space (Evans, 2003, Beil and Hanes, 2013), as those who have greater access to, or who are intentionally exposed to nature, generally report a variety of psychological benefits, ranging from stress reduction to improved self-esteem (e.g. Hartig et al., 2003, Keniger et al., 2013, Berman et al., 2008). However, despite an extensive body of work stretching back decades, studies examining the links between nature and human wellbeing have largely treated the urban natural environment as homogenous (Karmanov and Hamel, 2008, Velarde et al., 2007), with many researchers failing to define or describe the natural environment at all (Taylor and Hochuli, 2017, p. 28). Urban planning strategies often focus on the macro-variables of green space (e.g. size, access, green space area targets), with far less attention being paid to the micro-variables that might influence the quality of people's nature experiences and the wellbeing outcomes they derive from them (i.e. green space attributes). Additionally, studies examining people's aesthetic preferences for nature highlight an attraction to savanna-like environments and traditional styles of European parkland (Balling and Falk, 1982, Hill and Daniel, 2007, Williams and Cary, 2002). As such,

European aesthetic preferences have been transplanted via urban parks, into countries with decidedly non-European climates, such as Australia, where they are unsustainable (Raxworthy, 2010), and exhibit low levels of complexity and biodiversity that do not sustain vulnerable native species (Williams and Cary, 2002). Thus, compounded by the proportion of the population now residing in urban areas, "most people encounter biological uniformity in their day-to-day lives. This serves as a constant reminder of the presumed unimportance of biodiversity among those designing and governing our metropolitan areas" (Miller, 2005, p. 431).

1.1.2. Biodiversity and human wellbeing

Urban landscapes are where most people see and experience nature (Grose, 2012). However, urban nature is largely depauperate, for the reasons outlined above, and our conservation efforts are traditionally expended protecting nature outside of cities, e.g. in National Parks and wilderness areas. These places are experienced far less frequently by urban populations, and for many people, they will never be experienced at all. It is not surprising then, that most laypeople have a poor understanding of ecosystems and the important role biodiversity plays in our lives (e.g. Lindemann-Matthies and Bose, 2008). In light of this and a growing recognition of the need for research that examines the effects of green space attributes on human wellbeing, researchers have begun exploring the links between biodiversity and the attainment of psychological benefits.

Research attention in this area has grown over the past decade, spearheaded by an early study reporting a positive relationship between species diversity and psychological benefits in urban parks (Fuller et al., 2007). Although in its nascent stages, subsequent studies in this field have not had consistent findings (e.g. Dallimer et al. (2012) found no relationship between species diversity and psychological benefits). An overview of the body of work pertaining to biodiversity and wellbeing – provided in Chapter 2 – and a review examining the psychological benefits of direct biodiversity experiences –

provided in Chapter 5 – highlight several shortcomings in this field. The relationship between nature and human wellbeing is inherently complex and difficult to quantify, and this complexity is confounded by the difficulties involved in measuring the attributes of nature. Furthermore, unlike the physiological benefits provided by biodiversity (e.g. reduced rates of pathogen transmission (Ostfeld, 2017)), the attainment of psychological benefits may be dependent on people's ability to perceive biodiversity attributes – an ability that is thought to be quite poor (e.g. Shwartz et al., 2014). Furthermore, this ability has not been systematically examined in studies exploring the biodiversity-wellbeing relationship (e.g. Carrus et al. (2015) did not examine biodiversity perceptions, and although Fuller et al. (2007) did, they did not explore the relationship between those perceptions and the attainment of benefits). As such, it is not yet clear whether a relationship between biodiversity and wellbeing exists, and if it does, to what extent it is moderated by the public's perception of a concept with which they have likely had limited exposure. The review in Chapter 5 conveys that most research in this field has been correlational or comparative in design, despite calls for research that examines causality in the relationship between nature and wellbeing (e.g. Lovell et al., 2014, Clark et al., 2014). As such, there is a great need for experimental studies that control for the many variables that people experience during *in situ* nature experiences (e.g. weather, crowding, social interaction, duration of exposure) in order to further our understanding of this increasingly important relationship.

1.2. Overview of the problem

The wellbeing benefits derived from biodiversity may provide an avenue through which we can covey the "importance, wonder, and relevance" of ecological quality to the lives of urban people. Yet, despite decades of research into the relationship between psychological wellbeing and the natural environment, there remains much to be determined about the actual attributes of green space that are required to facilitate psychological benefits (e.g. Frumkin, 2003, Gascon et al., 2015, Franco et al., 2017), and it is not yet clear whether biodiversity does indeed facilitate improvements in psychological wellbeing.

Reviewing the body of work pertaining to biodiversity and wellbeing highlights four key limitations:

1. There is a dearth of knowledge about the attributes of natural environments that are required to facilitate positive psychological outcomes. For decades, a largely dichotomous approach to examining the benefits derived from broadly defined "natural" and "built" environments was adopted (e.g. Hartig et al., 2003, Velarde et al., 2007). As a result, researchers are only now beginning to examine the great variability that exists within nature, and the influence that micro-variables and attributes such as biodiversity might have on human wellbeing (Keniger et al., 2013).

2. The relationship between nature and wellbeing is inherently complex, which is further confounded when examining the variability that exists in nature. As such, research in this field employs a diversity of measures for quantifying the natural environment and the benefits it facilitates, many of which are resource- and time-intensive, such as biological surveys that limit the examination of this relationship to only a few sites (Fuller et al., 2007, Dallimer et al., 2012).

3. Research examining the effects of biodiversity on human wellbeing has not had consistent results (Lovell et al., 2014), and it has not systematically examined the role of biodiversity perceptions in the attainment of benefits from ecologically complex or valuable environments. Those studies that have examined perceptions, suggest the perceived biodiversity is more strongly related to wellbeing outcomes than objective measures (Dallimer et al., 2012). Furthermore, as highlighted in Chapter 2, the majority of this research has been conducted in the United Kingdom, with far fewer studies having been conducted in other parts of the world. Notably, no published research has directly examined the effects of biodiversity on wellbeing attainment at site-level scale in Australia.

4. There is a lack of experimental research examining causal relationships between nature attributes and wellbeing outcomes (Keniger et al., 2013, Lovell et al., 2014). Existing experimental methods employed in the environmental psychology field (e.g. the use of photographs and videos) have not kept pace with technological advancement. Whilst examinations of human responses to various natural environments may fail to detect a difference between conditions (e.g. Van den Berg et al., 2014), non-immersive laboratory experiences are not an accurate representation of nature experiences and may artificially inflate the belief that people prefer environments that are low in complexity or diversity. Smith (2015) outlines opportunities for the use of virtual reality (VR) research in examining relationships between people and natural environments.

Thus, this research project aims to contribute to several important gaps in the literature relating to nature-health relationships by delving into the attributes of natural environments that have a beneficial effect on human wellbeing in an Australian context; by examining attributes that have the potential to mutually benefit human beings and ecosystems in urban areas; by exploring the public's ability to perceive biodiversity and controlling for these perceptions; and by conducting experimental research that employs the latest in virtual reality technologies to ensure that this study represents the most authentic and immersive laboratory-based experience of biodiversity that has, to date, been used to examine the relationship between biodiversity and human wellbeing.

1.3. Thesis objectives

The overarching aim of this thesis is to explore the relationship between biodiversity and wellbeing in urban green space, and to address the research gaps highlighted in Section 1.2. Progress towards achieving this aim was guided by four research objectives, each of which was comprised of several research questions, as outlined in Figure 1.1.

The four objectives guiding this research were:

1. To determine what ecological attributes people value in their favorite environments and examine the relative importance placed on those attributes in the context of restorative experiences.
2. To evaluate whether people's perceptions of the environment reflect objective measures of environmental attributes considered important to ecosystem health.
3. To compare the relationship between objectively measured attributes of the environment, people's perceptions of biodiversity, and the wellbeing benefits they derive from urban parks.
4. To investigate whether there is a causal relationship between biodiversity and wellbeing outcomes.

1.4. Outline of the thesis

This thesis consists of four works which have been published, accepted, or submitted for publication. The four works are preceded by this Introduction (Chapter 1) and an outline of the Context in which the research was conducted (Chapter 2). Each publication, presented in Chapters 3 to 6, aligns with one of the research objectives outlined previously (see Figure 1.1). The thesis is concluded by a final Discussion (Chapter 7), which synthesizes the key findings and implications of the study, and sets forth recommendations for policy, planning, and future research.

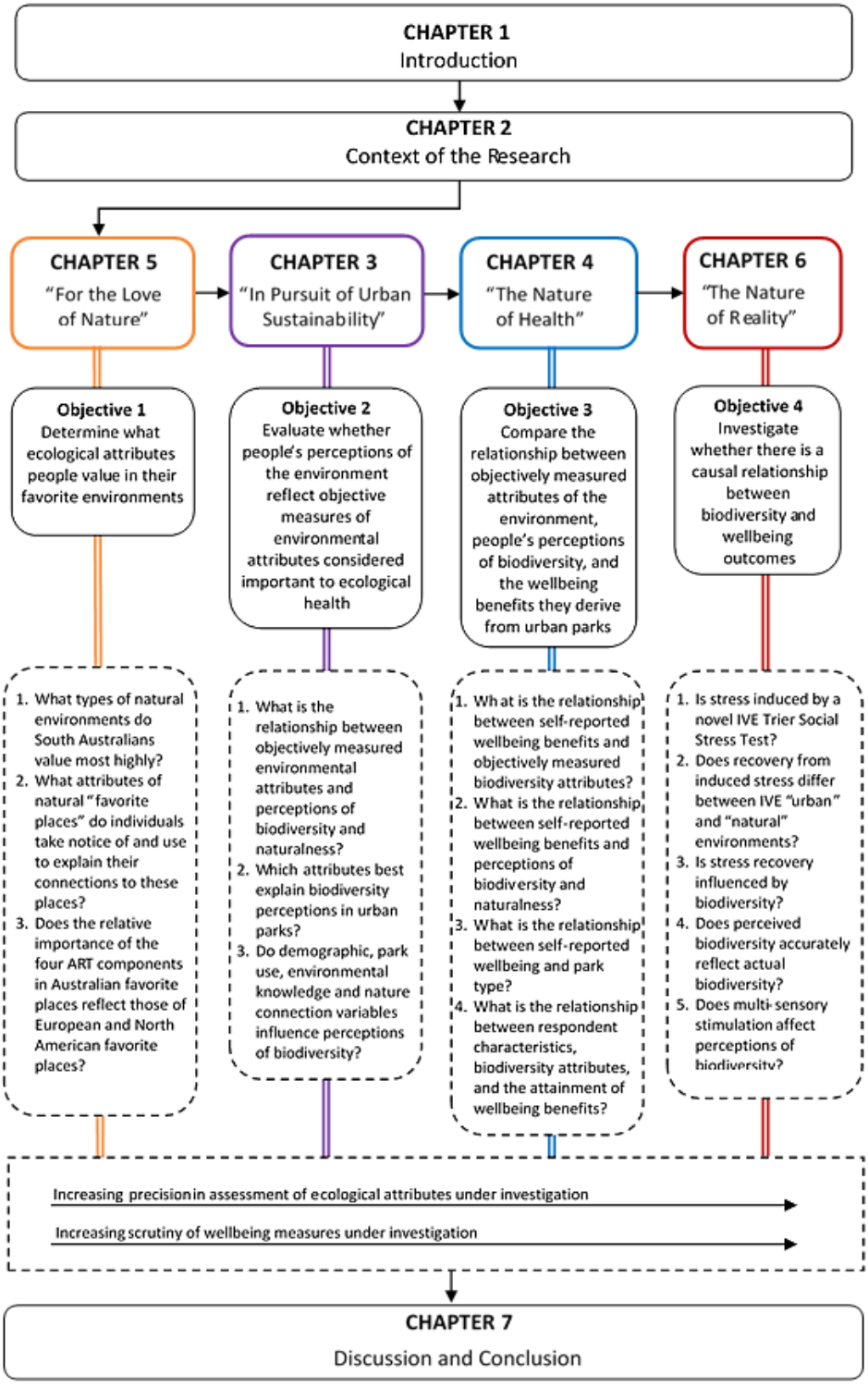


Figure 1.1. Graphical representation of the thesis structure. Outlined are the four research areas examined, the aims underlying each, and their integration in the overall body of work.

1.5. Conclusion

This thesis seeks to advance our collective understanding of the complex relationship between biodiversity and human wellbeing. The research presented here is significant because it addresses four key limitations of previous work and contributes to furthering our collective understanding of how we might attain sustainable socio-ecological systems, in which biodiversity and human wellbeing are balanced, even in cities. In this chapter, I gave a brief introduction to the problem, identified the key research gaps addressed by this thesis, and provided an overview of the thesis structure. In looking at the pressing issue of biodiversity conservation, this thesis turns our attention to the management of urban spaces, the places where we live, work and play. In doing so, it is hoped that this thesis will pave a way forward in the attainment of sustainable socio-economic systems, a way forward that is based not only on hope, but on sound scientific investigation and discovery.

Chapter 2. Context of Research

In this chapter, I provide an overview of the context in which this study was conducted. Firstly, I describe the historical and theoretical underpinnings of my research, followed by an outline of my research position and the approach I took to meeting the objectives introduced in Chapter 1. Lastly, I describe the methods I employed and discuss the assumptions and limitations of this work.

2.1. Historical context

In order to appreciate the contribution of a study that examines the wellbeing benefits associated with biodiversity in urban areas, it is important to first understand some key concepts in the conservation biology and environmental psychology literature, and how the two are integrated in this multi-faceted area of research.

2.1.1. Biodiversity

> *Biological diversity, or biodiversity, refers to "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 "*
> (United Nations, 1992, p. 3).

The importance of biodiversity to human wellbeing was formally recognized in 1992, with the formation of the Convention on Biological Diversity (United Nations, 1992), as well as subsequent supplementary agreements to the Convention such as the

Nagoya Protocol (the Aichi targets). Chief amongst the Aichi targets is that "by 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably" (United Nations, 2010, p. 2). Thus, the principal aim guiding the conservation of Earth's species acknowledges the paramount importance of people's "understanding, awareness and appreciation" of biodiversity (United Nations, 2010, p. 2). However, as 2020 draws near, data would suggest we have not made sufficient progress on this target. Since the Convention was developed, the global loss of species has accelerated, with species extinctions now occurring at a rate 1000 times the background, or pre-human, rate (De Vos et al., 2015), and our collective overexploitation of natural resources is placing ever-increasing pressure on biodiversity (Rands et al., 2010). The state of our environment is both a stark reflection of the value many societies place on nature, and a key impediment to the attainment of sustainable socio-economic systems. If we are to cultivate a world in which people have a sound "understanding, awareness and appreciation" of biodiversity, we must first realize the extent of the task ahead.

2.1.1.1. Public understanding of biodiversity

The language we use to communicate the importance of environmental issues to the public has been a topic of research for decades. To the ears of laypeople, the words we use may have a very different meaning to the one intended, for example, "exotic" in the context of conservation biology has negative connotations, but to the public the word is generally positive (Hassol, 2008). Other words may simply have no meaning to the public at all (Hassol, 2008), and there is concern that "biodiversity" may be one of those words (Novacek, 2008). Overall, it appears the public has a poor understanding of, and little familiarity with the concept of biodiversity (Lindemann-Matthies and Bose, 2008, DEFRA, 2011, Turner-Erfort, 1997, Hunter and Brehm, 2003, Buijs et al., 2008) and also with related ecological concepts such as ecosystem services (Thompson et al., 2016). In 2008, Lindemann-Matthies and colleagues found that 60% of their participants had never heard of the term biodiversity in Switzerland, mirroring earlier research in the United States in which 63% of participants had never heard of biodiversity (Turner-Erfort, 1997). In a qualitative study, Hunter and Brehm's (2003) question to the public about the meaning of biodiversity was most commonly met with confusion and an inability to provide an answer at all.

Furthermore, even when people "have grasped the meaning of biodiversity, they are often unfamiliar with the meaning and significance of biodiversity loss" (Novacek, 2008, p. 11572).

Whilst laypeople may not recognize the word "biodiversity" or be able to offer definitions of its meaning beyond the most superficial descriptions, there is some argument that the word is of limited use in public discourse, and not necessarily an indication of the public's views about the importance of conserving nature. However, as Robertson and Hull (2001, p. 971) write, there are "many possible natures" and any discussion of conservation must begin from an understanding of *what* we want to conserve in nature, and *why*. As conservation goals may be derived from, facilitated, or obstructed by the public, conservation efforts and outcomes can only benefit from the existence of an informed public with a sound understanding of biodiversity and the consequences of its loss. The costs associated with preventing and/or adapting to declining biodiversity will ultimately be borne by the public, so they must be equipped with the knowledge needed to make informed choices and influence the environmental decision-making process (Hunter and Brehm, 2003). Knowledge, however, is not enough to drive the behavior change required to improve many environmental issues; and appreciation of the construct is also necessary to motivate change (Bord et al., 2000).

2.1.1.2. Public awareness of biodiversity

The previous section describes a general lack of biodiversity knowledge amongst the public. Whilst knowledge can be considered a form of awareness, this section will explore awareness as perception, namely focusing on people's ability to detect biodiversity in their lives or in the environment around them, be it a region, specific site, or defined scene.

As with biodiversity knowledge, the public's awareness of biodiversity is thought to be quite poor. Studies demonstrate that people have widely inaccurate ideas about the number of species on Earth or in communities (e.g. Dunning 1997). Similarly, the public's ability to identify species is found to be very limited. Balmford and colleagues (2002) found that British school children were able to identify more

synthetic Pokemon 'species' than species of local wildlife. Similarly, in Lindemann-Matthies' (2002) study, Swiss school children could name very few taxa of local plants or animals, however, the researchers saw a mean increase of 2.6 new taxa being identified after students participated in an environmental education program of, on average, 17 hours of lessons over a 7-week period. More recently, Dallimer (2012) found that visitors to riparian green spaces had very inaccurate perceptions of bird, butterfly, and plant species richness, and similarly, in Shwartz et al. (2014) even park visitors who reported a strong preference for high levels of species diversity were unable to notice the diversity of species in parks they visited. In the two latter studies, biodiversity was generally under-estimated by the public. In another park-based study, French researchers compared the number of plant species identified by the public to those recorded by a professional botanist during a park walk (Muratet et al., 2015). On average, members of the public could identify three taxa (i.e. a broader level of identification than the species level), whereas the botanist identified 77 plant species. The plants identified by members of the public were also far more likely to be trees and exotic plants than those identified by the botanist. This is similar to the finding by Genovart et al. (2013) that Spanish children's ability to recognize exotic species is much better than their ability to recognize local species.

Although most studies show that laypeople do not accurately perceive biodiversity, some researchers have identified positive associations between objective measures of diversity and public perceptions. Fuller et al. (2007) found park visitors' perceptions of plant species richness correlated strongly with actual plant richness, however, perceptions of bird and butterfly species richness were not accurate. Similarly, Lindemann-Matthies et al. (2010) found that the perceived species richness of grasses and forbs increased with actual species richness when the public was presented with small arrays of potted plants on a table, with each array containing 49 plants but exhibiting a different number of species. Multiple arrays were presented at the same time, so respondents likely reported their perceptions of each array relative to the ones next to it. Whilst perceived species richness was generally associated with actual species richness, the researchers found that at low levels of species richness, the public overestimated the diversity of plants in the arrays, and at high levels of species richness, the public underestimated the diversity of plants in the arrays.

For the most part, research demonstrates laypeople's perceptions of biodiversity are not accurate, with only two studies finding a positive association between perceived biodiversity and plant diversity (Lindemann-Matthies et al., 2010, Fuller et al., 2007). In light of this, some researchers have posited that the public might rely on visual cues such as vegetation cover (Dallimer et al., 2012) or structural heterogeneity (Fuller et al., 2007, Jorgensen and Gobster, 2010) to inform their perceptions of biodiversity, as counts of species richness may be a scale of measurement that is too fine for most people to detect. In general, researchers comparing perceptions of biodiversity with objective measures of real environments have examined relatively few green spaces, ranging from a single site (Muratet et al., 2015) to 34 sites (Dallimer et al., 2012), and most of this research has been conducted in the United Kingdom (e.g. Dallimer et al., 2012, Fuller et al., 2007) and Europe (Muratet et al., 2015, Genovart et al., 2013, Shwartz et al., 2014). There does not appear to be any published research examining the relationship between perceived biodiversity and objectively measured biodiversity attributes in Australia. Whilst a lack of understanding about biodiversity and a limited ability to accurately perceive it do not bode well for conservation efforts, there is some suggestion that laypeople have an innate appreciation for biodiversity.

2.1.1.3. Public appreciation of biodiversity

Humans are thought to have a "passionate love of life and all that is alive" referred to as biophilia (Fromm, 1973, p. 365). Some researchers believe this affinity for living things is innate; a genetic predisposition that encourages us to seek out nature experiences, i.e. the biophilia hypothesis (Wilson, 1984). However, the theory is widely contested, with some researchers suggesting there is more evolutionary support for humans having developed biophobia – a fear of living things, such as snakes and mountain lions, than biophilia (Simaika and Samways, 2010). Regardless of one's viewpoint, there is broad support for evolution having influenced the way we perceive and value the natural environment. Intrinsically, most people believe that nature is important, however, the types of values placed on the environment by individuals are diverse (e.g. Kellert (1993) established a typology of nine different attitudes towards the environment, e.g. 'utilitarian' values derived from nature's usefulness to humans, and 'humanistic' values derived from an emotional attachment

to, or love for nature). The body of work pertaining to nature values is immense, thus, this section will provide an overview of aesthetic and utilitarian values, i.e. two key *affective* factors found to play an important role, for better or worse, in the public's support for biodiversity conservation (Martín-López et al., 2007, Simaika and Samways, 2010).

2.1.1.3.1. Aesthetic biodiversity values

People have touted the beauty of nature since the advent of written history, and this "appreciation and affection for beautiful environments is probably as old as humanity itself" (Perkins and Brown, 1999). Within the field of landscape preferences and scenic beauty assessments, there are two key lines of thought; the first suggesting landscape preferences are innate (evolutionary theories), and the second suggesting they are learnt (cultural theories). There is support for both lines of thought in the literature, and within each are positive and negative implications for biodiversity conservation.

According to evolutionary theories, modern landscape preferences are reflective of the landscape attributes that played a role in the survival of early humans (Steg and de Groot, 2013). Theories such as the biophilia hypothesis suggest human beings have an affinity for a diversity of species and landscapes, and it links such attributes to optimal human functioning (Steg and de Groot, 2013). Conversely, most evolutionary theories (and those with more supporting evidence) show an overwhelming preference for environments exhibiting savanna-like attributes such as openness, even/low ground surfaces, and scattered trees, perhaps because these attributes of the savannas of east Africa provided a survival advantage for human beings compared to other environments (Parsons and Daniel, 2002). Orians' (1980) habitat theory, Appleton's (1975) prospect-refuge theory, and Kaplan and Kaplan's (1989) preference matrix highlight the importance of savanna-like attributes to human aesthetic preferences. Prospect-refuge theory posits that savanna environments provided the right balance of vegetation and open areas where early humans could be seen without being seen (Appleton, 1975). Habitat theory further suggests that the savanna provided prospect-refuge but also provided for utilitarian needs such as food and shelter (Orians, 1980). From a biodiversity conservation perspective, these preferred landscapes are not ideal, e.g. the absence of understory provides greatly reduced habitat for many species of native wildlife (e.g. Ruddell et al., 1989), and "much of our urban and rural landscape that has

the structural character of a savanna is low in biodiversity and has been managed to discourage many ecological functions" (Gobster, 1994, p. 66).

On the other hand, cultural theories such as topophilia (Tuan, 1974) and the ecological aesthetic (Gobster et al., 2007) posit that landscape preferences are shaped by personal, social, and cultural characteristics (Steg and de Groot, 2013). Topophilia suggests that people will bond with environments they know well, and therefore, that familiarity and experience drive landscape preferences (Tuan, 1974). Topophilia is considered to be analogous with concepts such as sense of place and place attachment (Altman and Low, 1992). The ecological aesthetic highlights the importance of environmental knowledge in the development of landscape preferences, suggesting an understanding of ecological functions will lead to a stronger aesthetic preference for it (Gobster, 1999, Gobster et al., 2007). Whilst these cultural theories suggest there is greater potential to influence people's landscape preferences in regards to biodiversity, there are clear impediments to this. Firstly, as described earlier, people are thought to have a poor understanding of, and ability to perceive biodiversity. Secondly, if place attachments are more likely to develop in environments we have greater familiarity with, there is some concern about the "homogenizing" effect urbanization has on biodiversity (Dures and Cumming, 2010, van Rensburg et al., 2009, Miller, 2005) which limits people's exposure to, and familiarity with biodiverse environments. Whether a result of evolutionary forces or learned aesthetic preferences, many of the natural environments found in urban areas today reflect savanna landscapes, e.g. parklands and golf courses, and thus, these are the natural environments that many urban people come to be most familiar with. Of course, urban people will visit biodiverse natural areas outside of urban centers, however, in Australia, there is thought to have been a substantial decline in the percentage of people visiting significant natural areas such as National Parks, State Parks, or World Heritage Areas, i.e. 63% of the population reported visiting a significant natural area in 1991, but this declined steadily over the next 12 years to just 52% of the population in 2003 (ABS, 2004). As these data have not been updated more recently, visitation may have changed, however, as the frequency of nature trips in general held relatively steady between 2004 and 2012 (ABS, 2013), it is unlikely that visits to significant natural areas increased over this time.

Theory aside, research examining the aesthetic appeal of biodiversity has not had consistent results. In Qiu et al. (2013), participants took photographs in four different natural areas, with each photograph representing either a perception of high/low species richness, or something they liked/disliked in the environment. Photos of "liked" elements were significantly more likely to be associated with a manicured, ornamental park containing exotic plant species, and "disliked" elements were significantly more likely to be associated with a more biodiverse, multi-layered woodland environment containing higher species richness. Significantly fewer photographs of perceived high species richness were taken in the manicured park, suggesting participants were aware it was less biodiverse than the woodland. Furthermore, participants in Hoyle et al. (2017) perceived the least natural plantings (i.e. comprised of exotic plant species) and those with more flower coverage to be the most aesthetically pleasing. In Australia, Williams and Cary (2002) did not see significant differences in preferences for scenes differing in ecological quality or complexity. They did however see significantly lower preferences for certain types of native plants, such as *Allocasuarina* trees and shrubs. In Johansson et al.'s (2014) experimental study, participants significantly preferred an intermediate level of biodiversity in forest settings, however the intermediate biodiversity scene also appears to be most reflective of a savanna environment (i.e. it is the only scene with a grassy ground cover and scattered trees). In Gunnarsson et al. (2017) aesthetic preference ratings of nearby parks were generally higher for residents living near parks with higher biodiversity. On a whole, these diverse research findings do not demonstrate a consistent human aesthetic preference for higher or lower biodiversity.

The aesthetic appeal of natural environments or of individual species can be a powerful motivator for conservation (Stokes, 2007). While there is thought to be a high degree of universality in landscape preferences (i.e. savanna-like landscapes) that do not bode well for biodiversity conservation (Gobster, 2001), landscape perceptions can be influenced by culture, experience, and information (e.g. Kaplan and Kaplan (1989) provide examples of the latter, p. 106-108). That environments exhibiting high biodiversity are at times perceived to be less attractive, may be an impediment to conservation – however, these findings have not been consistent. In their recommendations for effective environmental communication, Thompson et al. (2016) suggest that the public prefers discussing the benefits that nature can provide, rather

than the impact of humans on the environment. These benefits may be used to cultivate an appreciation for biodiversity, and whilst the aesthetic appeal of biodiversity may not consistently deliver, there are many other benefits provided by biodiverse environments.

2.1.1.3.2. Utilitarian biodiversity values

The benefits human beings derive from natural environments are often referred to as ecosystem services. The Millennium Ecosystem Assessment (2005) classifies these ecosystem services into four categories: provisioning services (such as food), regulating services (such as water purification), supporting services (such as nutrient cycling), and cultural services (such as spiritual connection to nature). Whilst even depauperate environments will convey benefits to people, biodiversity affects the "quantity, quality and reliability of ecosystem services" (Mace et al., 2012, p. 21). Furthermore, biodiversity may be an indicator of ecosystem health (Costanza and Mageau, 1999) and is known to contribute to ecosystem resilience and vigor (e.g. Peterson et al., 1998, Tilman, 1996). In studying the relationship between people and nature, a key and consistent finding has been related to nature-derived wellbeing benefits. Subjective wellbeing encompasses aspects such as mood and satisfaction, as well as positive and negative emotions (Stiglitz et al., 2010, Pett et al., 2016). Although there is a substantial body of work highlighting the positive links between nature and human wellbeing, the links between biodiversity and wellbeing are less established.

2.1.2. Nature, human health, and wellbeing

Mental health may be negatively affected by living in an urban setting, with mood and anxiety disorders found to be more prevalent amongst urban populations (Peen et al., 2010). Lederbogen et al. (2011) demonstrate that growing up or living in a city has a negative impact on the social evaluative stress processing of humans, which puts them at greater risk of developing a mental illness. In Australia, more than 45% of the population will experience a mental disorder at some point in their lifetime (ABS, 2007), and 20% of the population in any given year (ABS, 2018). Despite this, only one third of Australians with a mental disorder will access mental health services or support

(ABS, 2007). Given these figures, the implementation of strategies that target not only vulnerable individuals, but whole communities, in the prevention and treatment of mental illnesses may be necessary. According to Townsend and Weerasuriya (2010, p. 84), ecologically based solutions to mental illness, such as the presence of urban green space, can be "affordable, accessible and equitable choices to consider." The presence of natural elements in urban areas, such as trees and parks, can be thought of as a form of upstream health promotion (Beil and Hanes, 2013, Maller et al., 2006), as contact with the natural environment is considered by many to provide an effective population-wide strategy in the prevention and treatment of mental illness (e.g. Maller et al., 2006).

Intrinsically, human beings have known for millennia that they derive wellbeing benefits from nature, e.g. there are references to the healing powers of nature in ancient Sumerian and Greek texts (Steg and de Groot, 2013). However, the relationship between nature and human wellbeing as a field of scientific research has a much younger history. Roger Ulrich's (1984) study of hospital patients with a view of nature "for the first time, provided reliable empirical evidence that exposure to nature may improve human health" (Steg and de Groot, 2013, p. 50). Since this time, a multitude of studies examining the wellbeing benefits of contact with nature have been conducted, and for the most part, this body of work supports the general premise that natural environments convey greater wellbeing benefits to humans than do urban or built environments (e.g. Hartig et al., 2003, Velarde et al., 2007, Maas et al., 2006, Keniger et al., 2013). This focus on comparing the benefits derived from broadly defined 'natural' and 'built' environments has predominated in the field (e.g. Hartig et al., 2003). This dichotomous approach has led to strong research frameworks and has been instrumental to initiatives that encourage people to spend time in nature, such as "Healthy Parks, Healthy People," (Maller et al., 2008) and from a planning perspective, in encouraging greater development of urban green space. However, the research dichotomy has not, until recently, recognized the great variance that exists within nature, and indeed, after decades of research into the nature/wellbeing relationship, much remains unknown about the attributes of green space that are required to facilitate psychological benefits (e.g. Frumkin, 2003, Nordh et al., 2009, Keniger et al., 2013). Furthermore, as the state of the natural environment continues to deteriorate, research attention is turning

increasingly to examining the effect of ecologically valuable attributes such as biodiversity, on psychological wellbeing.

2.1.2.1. Biodiversity and human wellbeing

Within the field of nature-health relationships, research into the importance of biodiversity, or perceived biodiversity, to mental health has only just begun to be explored (Dean et al., 2011). Until recently, studies of biodiversity from a human wellbeing perspective only examined the effects of biodiversity loss on human physical health, for example, the reduced numbers of plant and animal species available for food, fiber and medicine (Alves and Rosa, 2007). However, since 2007, research examining the psychological benefits associated with biodiversity has become more prevalent, and although the results of this research have not been conclusive, the field is still in its nascent stages.

The first study examining a link between biodiversity and subjective wellbeing was conducted in the United Kingdom (Fuller et al., 2007). Plant, bird and butterfly species richness were assessed in 15 public urban green spaces, and their linear relationship with respondents' self-reported psychological benefits was modeled. The study also explored respondents' perceptions of species richness in order to determine the accuracy with which park users are able to perceive biodiversity, however, they did not use these perceptions to examine their effects on the benefits derived. The study found that psychological benefits – as determined by self-reported measures of perceived restoration, positive emotional bonds and sense of identity gained from the green space – were positively related to the actual species richness of plants, and to a lesser extent, birds (Fuller et al., 2007). No relationship was found between psychological benefits and butterfly species richness. Perceived plant species richness increased with measured plant species richness, however, respondents did not accurately perceive bird, nor butterfly diversity. The authors posited that structural heterogeneity might be a key visual cue influencing park visitors' perceptions of biodiversity.

Whilst Fuller et al. (2007) identified a positive relationship between objectively measured species richness and psychological benefits, Dallimer et al. (2012) found no consistent relationship between actual species richness and psychological wellbeing benefits amongst park users. Dallimer et al. (2012) did, however, determine that psychological benefits increased with perceived biodiversity, despite this being inaccurately detected by respondents. Species richness was assessed using the same site sampling methods as Fuller et al. (2007), however, in a greater number of parks (34 riparian green spaces in the United Kingdom). Dallimer et al. (2012) suggest vegetation cover may be a key visual cue influencing people's perceptions of ecological attributes such as biodiversity and naturalness. If biodiversity perceptions, rather than actual biodiversity, are more strongly associated with wellbeing benefits, the public's limited ability to accurately perceive the diversity of species around them (see Section 2.1.1.2) may be a key impediment to communicating the benefits of biodiversity to laypeople.

In a Taiwanese study (Chang et al., 2016), green space biodiversity was not associated with any increase in physiological wellbeing (e.g. heart rate, blood volume pulse), however, biodiversity was assessed via the species richness and evenness of insects, which may once again highlight the importance of biodiversity perceptions to the attainment of wellbeing benefits. Sikorska et al. (2017) found no relationship between aquatic, rush, and terrestrial plant diversity around lakes and the frequency or duration of visitation. Whilst green space "use" is a frequently studied benefit in nature-wellbeing research – and park use is often associated with improved human wellbeing – in and of itself, contact with nature is not a direct measure of human wellbeing. These two studies demonstrate the heterogeneity in wellbeing measures that have been explored in this body of work, ranging from physiological to indirect or implied benefits. Neither study examined subjects' perceptions of biodiversity in these settings.

Several studies have examined the relationship between biodiversity and perceived restorativeness as a measure of wellbeing (albeit, they have used different measures of restorativeness). Wood et al. (2018) found that ecological richness (i.e. a combined measure of plant, bird, and butterfly species richness, and the number of habitats present) explained 43% of the variance in respondents' perceived restorativeness.

Similarly, Carrus et al. (2015) found that perceived wellbeing and perceived restorativeness were associated with biodiversity when using a simple four-park typology (high versus low biodiversity in urban versus peri-urban green space). Once again, neither of these studies examined biodiversity perceptions.

Other researchers have examined the wellbeing benefits associated with ecological concepts related to biodiversity, such as naturalness and wildness. Van den Berg et al. (2014) examined the effects of naturalness on wellbeing using an experimental study involving videos of different environments. They found no significant differences in mood or restorative state between natural scenes. When examining perceptions of naturalness they found some association between perceived naturalness and perceived vitality. Martens and colleagues (2011) assessed participants' wellbeing before and after a 30-minute walk in either a "wild" or "tended" forest. Participants who walked in the tended forest experienced significantly greater increases in positive affect and significantly greater decreases in negative affect, than those who walked in the wild forest.

Further studies have examined wellbeing and biodiversity on a much broader scale than the individual sites included in the above studies. In Mexico, Tagles and Idrovo (2012), analyzed aggregate-level biodiversity across Mexican states and examined associations with depressive symptoms. They found that depression increased in states with greater levels of biodiversity. However, the authors suggest that biodiversity is likely to be higher in rural areas where socio-economic conditions may be so unfavorable that they override any potential benefit associated with contact with nature. They posited that in Western societies, where socio-economic conditions are generally more favorable, biodiversity may be more likely to have a positive effect on psychological health (Tagles and Idrovo, 2012). There may be some support for this, as in an Australian study, when researchers controlled for demographic variables, respondents' self-reported "neighborhood wellbeing" (satisfaction with their neighborhood) was positively associated with vegetation cover and the species richness and abundance of birds in their neighborhood (Luck et al., 2011). In terms of personal wellbeing, however, demographic variables explained more of the variation in responses than neighborhood environment characteristics.

When taken together, the findings of biodiversity-wellbeing research are far from consistent, however, they do suggest that the relationship is worth exploring further. At this point in time, there appears to be little consistency in the methods used to assess biodiversity (ranging from time-consuming biodiversity surveys to simple park typologies) or measure wellbeing (ranging from EEG, to self-reported restorativeness, to neighborhood satisfaction), however, this will change quickly as the body of work grows. Notably, 8 of the 13 studies examining the biodiversity/wellbeing relationship at a site scale (e.g. in specific parks) have been conducted in the United Kingdom, displaying a clear geographic disparity in the literature. No published studies examining the relationship at a site scale appear to have been conducted in Australia. Furthermore, the studies have largely been comparative or correlational in nature, with only one controlled experimental study, which examined biodiversity and brain activity as a measure of wellbeing (Johansson et al., 2014). Lastly, researchers have not consistently included measures of perceived biodiversity as well as actual biodiversity in their assessments, to determine the extent to which accurate biodiversity perceptions are necessary for the existence of a positive biodiversity/subjective wellbeing relationship.

2.1.3. Overview of key theory

In recent decades, two key theories have been posited to explain the relationship that exists between nature and human wellbeing: Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989), which relates to the ability of natural environments to restore cognitive functioning, and Psycho-physiological Stress Recovery Theory (SRT) (Ulrich, 1983), which relates to the ability of natural environments to initiate a relaxation response. These two theories, which have been central to environmental psychology research since their inception, help to explain the mechanisms by which natural elements have a positive effect on human wellbeing. They are considered to be different but complementary theories. Both theories describe the types of broad features a natural setting should contain in order to aid recovery from acute stress (SRT) and prolonged stress or cognitive fatigue (ART). In this thesis, “stress” is a key measure of wellbeing, due to its direct relevance to modern people.

2.1.3.1. Stress

Unlike most psychological conditions, stress is a "common and seemingly inevitable aspect of life" (Baum and Posluszny, 1999, p. 140). Poorly managed stress is often a precursor to some of the most frequently occurring psychological conditions, such as anxiety, depression, and substance abuse disorders. Ineffective stress recovery may undermine physical and mental health through chronic arousal and immune suppression (Van Den Berg et al., 2007), and stress is now considered to be an epidemic public health concern that negatively impacts cardiovascular, gastrointestinal, immunological, neurological, endocrine, mental and emotional health (Beil and Hanes, 2013). According to Bird (2010), modern medicine has little to offer chronic stress in terms of treatment and prevention, because the causes of chronic stress are so diverse. Stress recovery has been shown to be greater in natural environments than in built environments (e.g. Beil and Hanes, 2013), however, few studies have explicitly examined subjective "stress" in biodiversity and wellbeing research. Although Van den Berg et al. (2014) induced stress in their psychological experiment, the wellbeing measures included in the study were only indirectly related to stress, i.e. they assessed recovery in mood, vitality, and restorative state. Furthermore, the authors' assessed recovery during exposure to environments differing in naturalness, rather than biodiversity. Creating an everyday living environment in which recovery from stress is encouraged and facilitated may be an effective method for preventing a range of serious health consequences, and improving quality of life for many people.

2.1.3.2. Attention Restoration Theory

Attention Restoration Theory (ART) – devised by Rachel and Stephen Kaplan in the 1980s – is a dominant model within the field of environmental psychology. The theory suggests that people have two types of attention: directed attention and involuntary attention. Directed attention requires a person to exert effort to maintain their focus on the task at hand, and to process the information received (Kaplan and Kaplan, 1989,

Bird, 2007). The person does not find the task fascinating, and as it holds little interest, effort is required to block out other, more interesting stimuli that compete for their attention (Irvine et al., 2013). During a person's day-to-day life, many tasks, such as reading, will require directed attention. Eventually, a person's capacity to block out competing interests diminishes, and they become cognitively fatigued. Cognitively fatigued people become easily distracted; can no longer concentrate; have a diminished ability to plan; reduced patience; and increased irritability (Bird, 2007).

According to ART, natural environments facilitate recovery from mental fatigue because they contain softly fascinating stimuli, which hold a person's attention without effort (Irvine et al., 2013). However, according to Kaplan & Kaplan (1989) fascination is only one of four criteria a natural environment must meet in order to be restorative:

- *being away* i.e. they must be in a distinct location, which is geographically and/or psychologically distant from the tasks and routines that demand directed attention;
- *extent* i.e. the extent to which a person can be involved in and explore the environment;
- *fascination* i.e. the ability of the environment to capture a person's involuntary attention; and
- *compatibility* i.e. the match between what a person wants to do, can do, and must do within the environment.

2.1.3.3. Psycho-physiological Stress Recovery Theory

Psycho-physiological Stress Recovery Theory, or Stress Reduction Theory (SRT) was proposed by Roger Ulrich in 1983. The stress response is a physiological and psychological reaction that is activated by the sympathetic nervous system, and occurs in response to a perceived threat. This natural response is essential to survival, i.e. 'the fight or flight' response that enables a person to quickly avert danger. However, in many cases, the stress response can be activated by stressors that are not life-

threatening, such as traffic jams, public speaking, or an excessive list of emails requiring response. The opposite of the stress response is the relaxation response, which is mediated by the parasympathetic nervous system (Irvine et al., 2013). According to Ulrich (1983) and many other researchers (e.g. Van Den Berg and Custers, 2011), natural environments are effective at inducing an immediate relaxation response. As opposed to ART, which posits that natural environments stimulate a cognitive response in humans, SRT suggests natural environments stimulate an affective, or emotional response. Ulrich (1983) suggests this is a remnant of human evolution, as in the biophilia hypothesis (Wilson, 1984). As humans have an evolutionary connection to the natural environment, they often find nature more aesthetically pleasing than man-made environments, as discussed previously. This positive aesthetic response is linked to one's emotional and cognitive state, as well as one's behaviour, thinking, and neurophysiological activity (Ulrich, 1983). Ulrich (1986) suggests natural environments are more likely to be preferred, and therefore stress-reducing, when they exhibit:

- *complexity*, with a moderate to high number of visual elements;
- *structure*, when these visual elements establish a focal point or pattern;
- when the *depth* of visual field is moderate to high;
- the ground surface is *uniform* and allows for ease of movement;
- the landscape has a *curving sightline* that suggests there is more to the environment just outside of the viewer's sight; and
- the *perceived threat* to safety is minimal or absent.

2.2. Research position and strategy

In conducting this study, I adopted a pragmatic worldview, whereby, rather than focusing on methods, researchers emphasize the research problem and use all approaches available to understand it (Rossman and Wilson, 1985). In this case, the research gaps identified in the first two chapters of this thesis were tackled using a mixed method approach, as is frequently adopted by pragmatic researchers (Johnson and Onwuegbuzie, 2004). More specifically, I adopted an exploratory sequential mixed method approach (Creswell, 2014), beginning with a qualitative research phase, the results of which were used to inform second, third, and fourth quantitative phases

comprised of on-site assessments, a public survey and an experiment, respectively (see Figure 1.1 in previous chapter).

2.3. Research framework

Shanahan and colleagues proposed a research framework in 2015 that would help researchers contribute to identifying the pathways to health benefits from nature. Although I did not adopt this framework, since my research was already underway, my own research framework closely mirrors the one recommended by those researchers, who have been responsible for some of the most influential work in this field (e.g. Fuller et al., 2007). Thus, in Figure 2.1 I have overlaid my own research framework over the one proposed by Shanahan and colleagues.

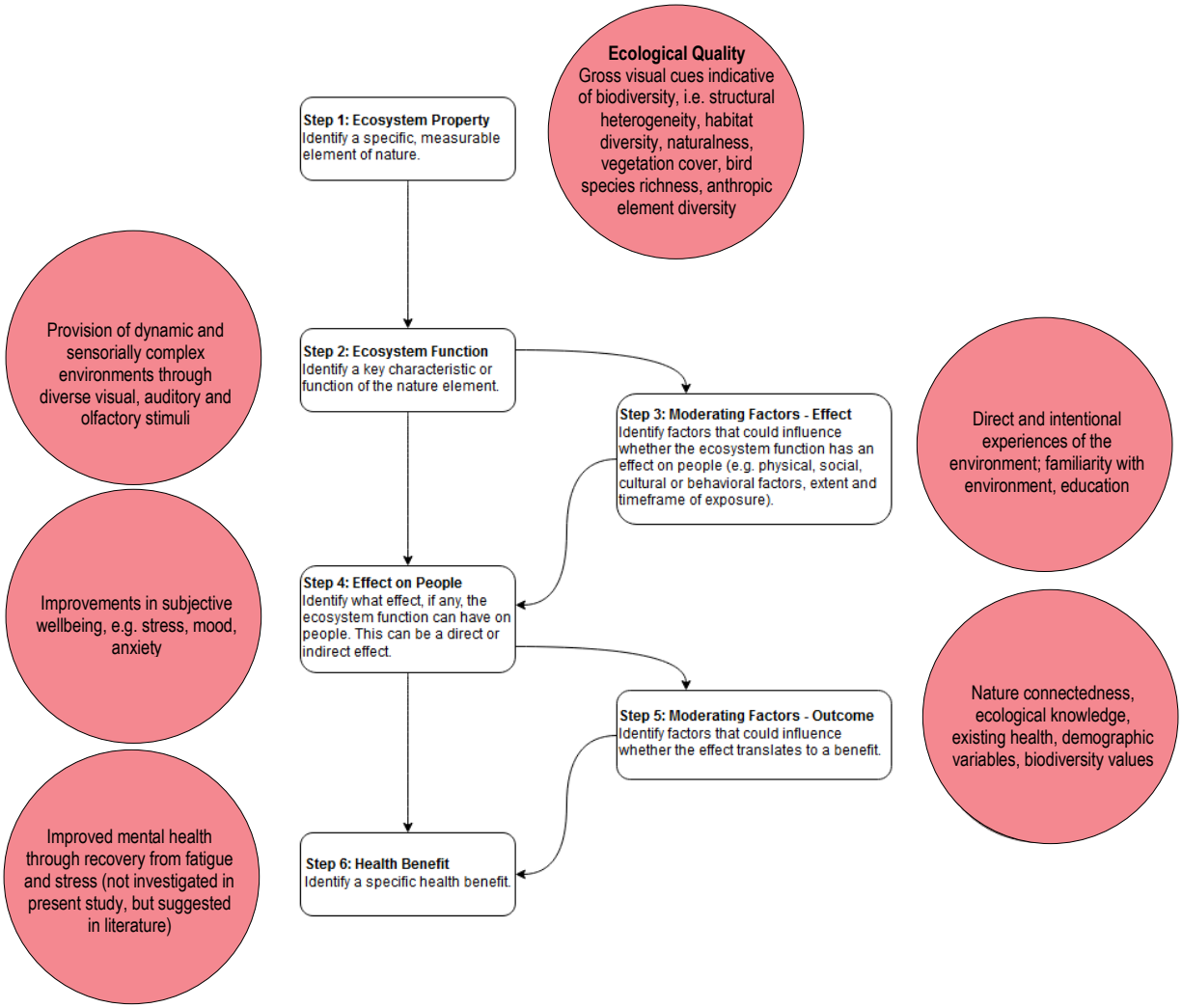


Figure 2.1. Adaptation of the research framework proposed by Shanahan et al. (2015) for identifying the pathways to health benefits from nature. Circles added to represent the factors and characteristics I examined.

2.4. Study regions

In the first phase of this study (Chapter 3), 1 targeted the broader state populace of South Australia (Figure 2.2). In the second and third phases, I focused on the natural environments (Chapter 4) and residents (Chapter 5) of three inner city council areas (Local Government Areas) near Adelaide, the capital city of South Australia, i.e. the Cities of Burnside, Unley and Mitcham. Together, they have a combined population of 150,000 people – representing approximately 11.5% of the Greater Adelaide population

(Australian Bureau of Statistics, 2017d) (Figure 2.3). The final phase of the study (Chapter 6) was conducted in Mawson Lakes, a metropolitan suburb approximately 14 kilometers from the Adelaide city center. The city of Adelaide lies toward the southern coast of South Australia. It has a mediterranean climate, and as such, the city exists within one of the Earth's rarest and most biodiverse terrestrial biomes (i.e. the Mediterranean-type ecosystem, which covers just 2% of the Earth's land surface), and is considered to be a global conservation priority (Cox and Underwood, 2011, Myers et al., 2000).

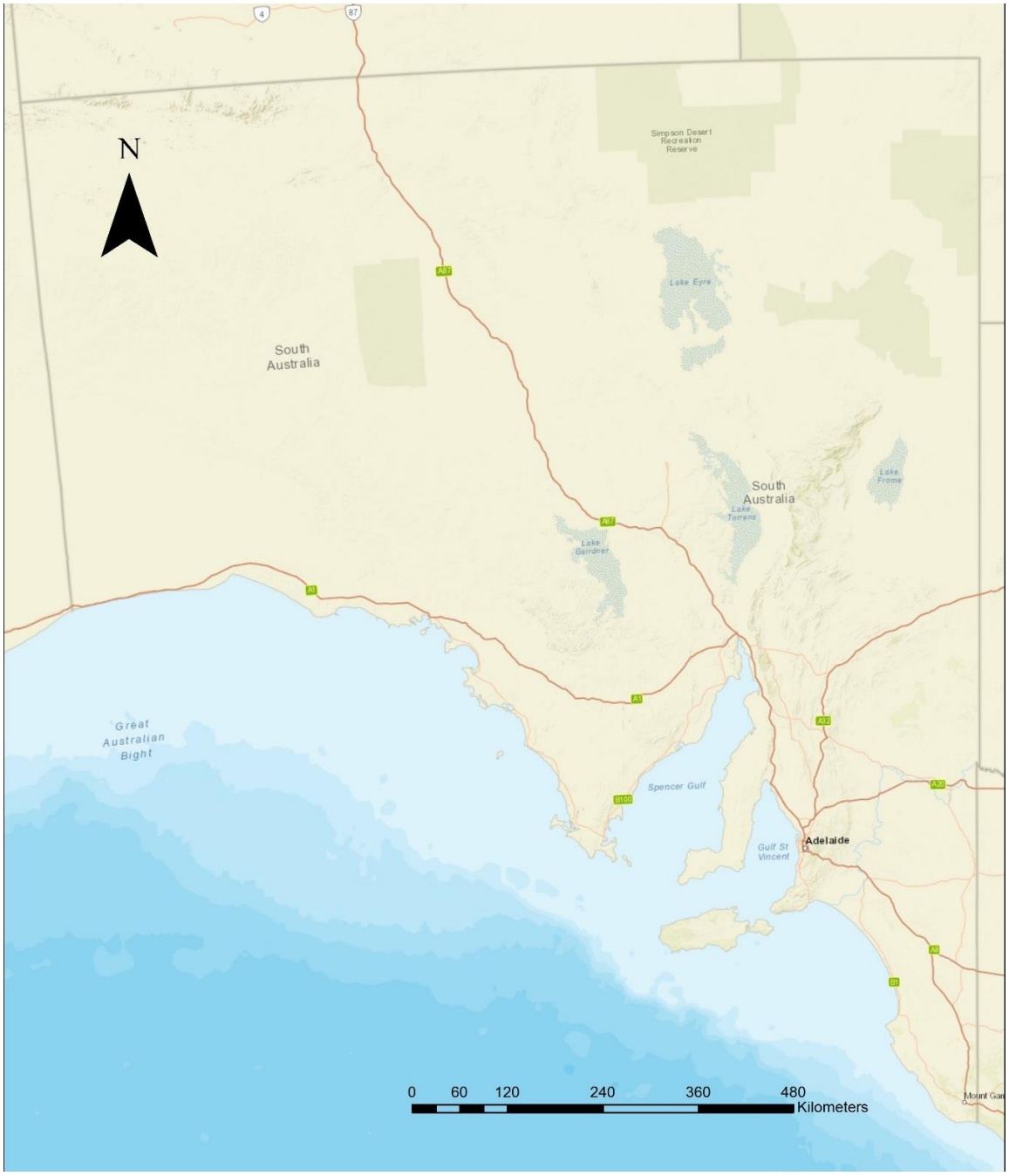


Figure 2.2. Map of study location, the state of South Australia.

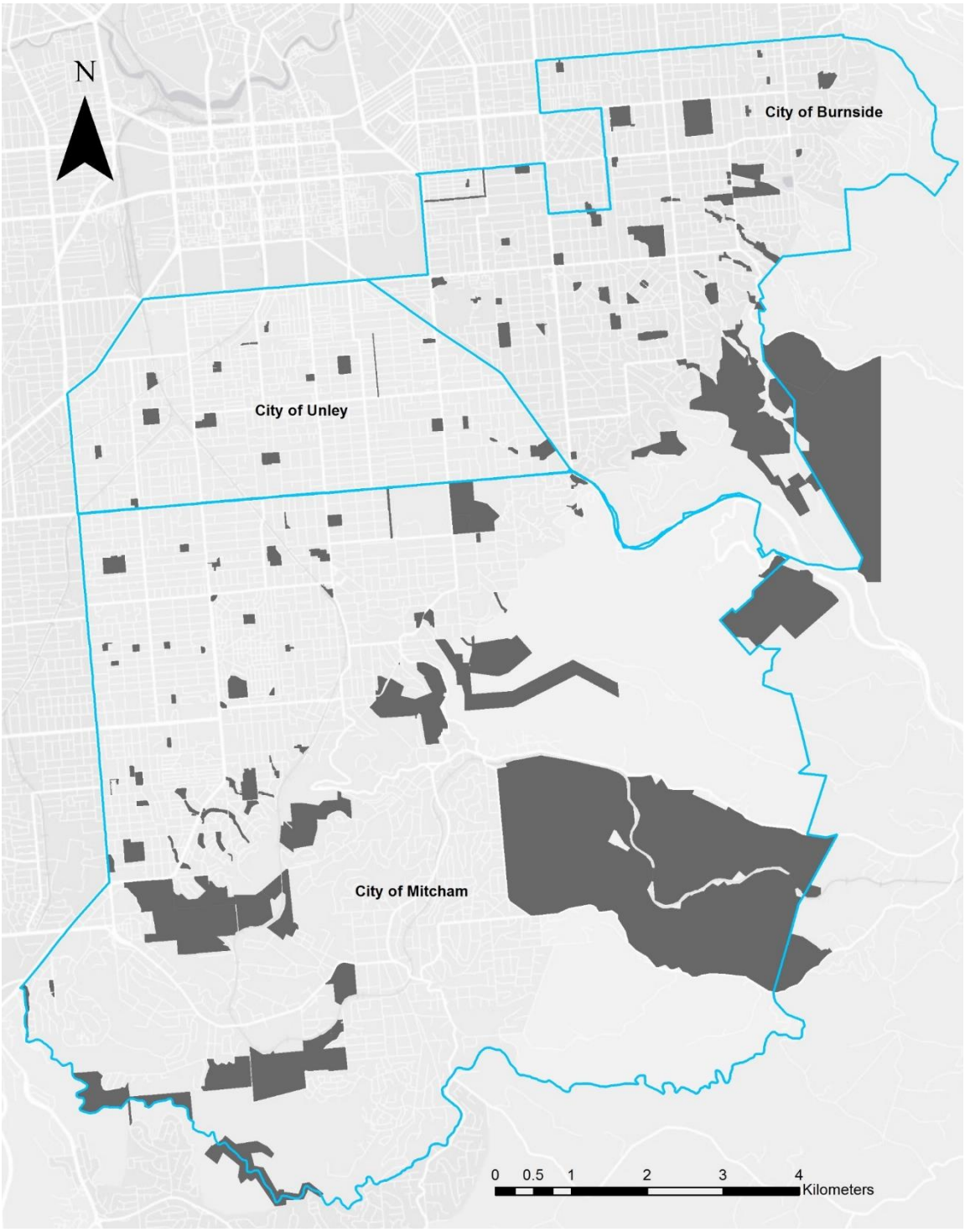


Figure 2.3. The three study areas: The City of Unley, The City of Burnside, and the City of Mitcham. Public green space is shaded in dark gray. A labelled map of all green spaces in the study can be found in Appendix A.

2.5. Overview of methods

I employed social survey and experimental research methods to address the objectives of this thesis. The methods are described in Chapters 3-6, however, here I describe the overall sequence in which the methods were used.

- In the research element described in Chapter 3, I took a qualitative approach to identifying the types of attributes that people value in their favorite places. To do this, I used a short online questionnaire, which contained two open-ended questions, along with a range of demographic questions (Appendix B). This questionnaire was administered to the broader South Australian population via promotion at various public events and on public radio (Australian Broadcasting Corporation). It was completed by 447 respondents.

- In the research element described in Chapter 4, I conducted a review of existing assessment tools for measuring the ecological quality and attributes of natural environments (Appendices C-E). Based on these and considering characteristics of urban parks in Australia, I developed my own rapid assessment tools and used them to assess the attributes of more than 120 urban parks in the Cities of Mitcham, Burnside, and Unley. I then administered a 12-page mail-back questionnaire (Appendix F) to the residents of these areas, exploring perceptions and benefits of green space, which was completed by 840 respondents. In Chapter 4, I compared respondents' perceptions of biodiversity and naturalness to objective measures of environmental attributes from my on-site assessments.

- In the research element described in Chapter 5, I examined the self-reported wellbeing benefits derived from urban parks (Appendix F), and looked at the relationship between those benefits and both objectively measured and perceived biodiversity attributes.

- In the research element described in Chapter 6, I conducted a laboratory-based immersive virtual environment (IVE) psychological experiment. During the experiment, in which I first induced a stress response in participants, I measured

psychological wellbeing using Visual Analog Scales (VAS) (Appendices P-Q) and physiological wellbeing using an Empatica E4 wristband that recorded heart rate and electrodermal activity (Figure 2.4).



Figure 2.4. The Empatica E4 wristband worn by the IVE experiment participants (image sourced from empatica.com).

2.5.1. Sampling

In the first phase of the study – the state-wide survey – I was fortunate to include my two open-ended research questions in a larger online questionnaire being conducted for a study called "Operation Outdoors". In return, I was responsible for administering the public questionnaire, creating and managing a Facebook page to promote the project, and liaising with the public at a series of public events. In addition to the latter two methods, the study was also promoted via public radio. My two open-ended questions were completed by 447 respondents from across South Australia.

In the next phase of the study, I first distributed 150 postcards inviting people to participate in an online questionnaire (Appendix G) and 150 mail-back questionnaires (Appendix F) to households within the study area. Given the financial investment that would be required to print mail-back questionnaires, maps, and reply-paid envelopes for

this study, an online survey seemed an attractive option, however as I had previously achieved a low response rate to an online survey about the benefits people attain from park experiences (Brown et al., 2014), I was determined to compare the use of online versus paper-based surveys via a pilot study. This initial test showed a substantial difference in the number of respondents to the online and mail-back questionnaires (1.3% response rate for the online questionnaire and 26% for the mail-back questionnaire). Thus, 4000 written questionnaires were distributed to every third household along selected streets in the three Council areas. This number represented just over 15% of all households in the study region. In selecting streets to target, each Council area was first divided into zones and allocated a proportion of the questionnaires (Appendix H). To ensure questionnaires were distributed across the entire study area, within each zone, a mix of major and secondary roads were identified and then targeted during questionnaire distribution.

In the experiment, participants were invited to participate via a school-wide email invitation sent to staff in my department at the University of South Australia (i.e. the School of Natural and Built Environments) and through word-of-mouth. Potential participants were required to complete an online screening questionnaire (Appendix I) to ensure that participating in the experiment would not put them at risk, and to rule out some key medical conditions that might interfere with the recording of physiological data (e.g. heart conditions). Accepted participants were randomly allocated to one of five experiment conditions: urban, low biodiversity, moderate biodiversity, high biodiversity multi-sensory, and high biodiversity visual-only. An assistant, Matin Kor, helped me conduct the experiment by loading the IVE scenes while I conducted the experiment procedure. In following the experiment procedure described in Chapter 6 (and shown in Appendix J), I adhered to a strict pre-determined script to ensure, as far as was practicable, that the only difference people experienced was the level of biodiversity that they experienced in the IVE scene (Appendix K).

2.5.2. Analyses

I employed a range of different statistical tests and content analysis techniques to address the objectives of this thesis. In Chapter 3, directed content analysis of qualitative data took either an inductive or deductive approach, depending on the particular aim I was addressing. I used inductive content analysis when existing research was not strong enough to guide the categorization of participants' responses (i.e. loved attributes), and I used deductive content analysis when existing research provided a strong foundation on which to base the categorization of responses (i.e. Attention Restoration Theory). In Chapters 4-6, statistical methods of analysis can be divided into those that sought to examine relationships between variables (e.g. modelling the association between park attributes and wellbeing benefits through the use of ordinal regression, linear regression, Pearson and Spearman correlations), and those that sought to examine differences between variables (e.g. chi-square, independent and paired t-tests, one-way ANOVA). Where the assumptions of parametric tests could be met, they were employed, however, when my data violated the assumptions, I employed the equivalent non-parametric tests.

2.6. Limitations

This research was restricted to participants from a single Australian state, which limits the generalizability of the findings to other populations. Whilst attempts were made to recruit a variety of participants (i.e. from three different samples) there are some inherent limitations in this study:

2.6.1. Sampling

The majority of respondents in all phases of this research were well educated, and had attained higher levels of formal education than the general South Australian population.

The Cities of Mitcham, Burnside, and Unley are quite affluent areas, which may further limit the generalizability of findings from the second and third phases of the study. The sample size in the IVE experiment (Chapter 6) was quite small, however, those results that did reach statistical significance had a large effect size, suggesting the sample size was adequate.

2.6.2. Measurement

Measuring human wellbeing is inherently difficult, and is perhaps one of the biggest limitations of my research. In Chapters 4-6, I measured wellbeing using single-response Likert scales or Visual Analog Scales (VAS). While I am confident in my justifications for doing so (e.g. as discussed in Chapter 5: the importance of personal awareness of benefit attainment and the length of the questionnaire), and for the most part used existing, validated scales (e.g. Davey et al., 2007), the use of multiple-response standardized questionnaires would have been preferable.

In Chapters 4 and 5, respondents provided self-reported data about their perceptions and benefit attainment in multiple parks that they visit and were familiar with. Self-reported data in itself is a common limitation in social science research (i.e. we must assume that respondents are answering truthfully), however, the remote nature of my questionnaires is a further limitation of this thesis (i.e. respondents did not complete the questionnaires in situ, and had to rely on their memory of each site, which could be selective). However, despite the latter limitation, I feel that these memory-dependent responses are likely to be a more accurate reflection of how people feel about certain places overall, even if they are not related to a given time point.

2.7. Conclusion

In this chapter, I discussed the history and importance of biodiversity conservation, and the different ways biodiversity is valued, perceived, and benefited from by human beings. I then provided an overview of the theoretical foundations for this study by

introducing Attention Restoration Theory and Psycho-Evolutionary Stress Reduction Theory. The chapter ended with a rationale for my research strategy and an overview of the methodology that I employed. It is clear that the conservation of biodiversity is one of the most pressing environment issues of our time. Developing an understanding of the nuanced relationship between people and nature, and the benefits they derive from biodiverse environments will be critical to its protection, and to the development of sustainable socio-economic systems. In the following chapters of this thesis, I present and discuss the findings of four separate studies. These studies are related to the four objectives outlined in Chapter 1, beginning with the identification of loved attributes in people's most valued natural environments.

Chapter 3. For the Love of Nature: Exploring the importance of species diversity and micro-variables associated with favorite outdoor places

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3.1. Abstract

Although the restorative benefits of nature are widely acknowledged, there is a limited understanding of the attributes of natural environments that are fundamental to restorative experiences. Faced with growing human populations and a greater awareness of the wellbeing benefits natural environments provide, park agencies and planners are increasingly challenged with balancing human and ecological outcomes in natural areas. This study examines the physical and experiential qualities of natural environments people referred to when describing their connection to their most valued natural environments in an online questionnaire. Recruited primarily via a public radio program, respondents were asked to identify their favorite places and explain what they loved about those places. Favorite places are considered exemplars of restorative environments and were classified based on an existing park typology. Reasons people liked particular sites were classified into three domains: setting, activity or benefit. Content analysis was used to identify the attributes most commonly associated with favorite places. These attributes were then related to the four components of restorative environments according to Attention Restoration Theory. In contrast to previous research, we found that 'fascination' was the most important component of favorite places. Possible reasons for this contrast, namely, respondents' median age, and the likelihood of a high degree of ecological literacy amongst the study population are discussed. South Australians' favorite environments comprise primarily hilly, wooded nature parks and botanical gardens, in stark contrast to the vast arid areas that dominate the state. Micro-variables such as birds, plants, wildlife, native species, and biodiversity appear particularly important elements used to explain people's love of these sites. We discuss the implications of these findings and their potential value as an anchor for marketing campaigns seeking to encourage contact with nature, as well as education programs designed to improve people's understanding of important but intangible concepts such as biodiversity. The findings have clear, practical implications for park managers given the modifiable nature of many of the attributes identified as being most important to our respondents, and we believe attention to such elements has the potential to simultaneously enhance people's nature experiences, optimize restorative outcomes, and improve environmental stewardship.

Keywords

Biodiversity; ecological literacy; favorite places; nature connectedness; restorative environments

3.2. Introduction

For many people, contact with nature is no longer a by-product of everyday life. For the vast majority of human history, we relied upon the natural environment for food, water and shelter in very direct and unambiguous ways, as all species do. Today, although we are equally dependent upon the environment to sustain us, the majority of the world's population now resides in towns and cities (The United Nations, 2014), where they are largely sheltered from the natural processes and ecosystem services that make their existence possible (Miller, 2005). The consequences of this separation between 'people' and 'nature' are two-fold. Firstly, as each succeeding generation becomes increasingly disconnected from the natural world, the collective importance placed upon the environment by urban populations is likely to diminish (Pyle, 2002). In turn, this may lead to reduced advocacy and funding for conservation and biodiversity protection, which has long-term global implications. Secondly, a lack of contact with the environment is thought to be a contributing factor to the increasingly poor health and wellbeing of urban inhabitants (Maller et al., 2008), which some scholars suggest is the result of a failure to fulfil our inherent biological need to spend time in nature (Wilson, 1984).

In order to develop policies and practices that see contact with nature become commonplace again, we must first understand the activities, environmental settings, and benefits that encourage people to seek out nature experiences. As exemplars of restorative, health-giving environments, we believe investigating perceptions of 'favorite places' and the attributes people describe when explaining their connection to these settings will provide valuable information for urban planners seeking to optimize the health benefits of nature. In this paper we explore the attributes of outdoor environments that people place great personal importance on and consider the implications of these findings to modern societies.

3.2.1. The psychological benefits of contact with nature

The wellbeing benefits of contact with nature has long been a topic of interest to researchers across diverse disciplines, and there is now a broad evidence base supporting a positive relationship between human health and nature (e.g. Velarde et al., 2007, Keniger et al., 2013). The influence of the quality of natural environments on mental health, and the relative importance of individual environmental variables on psychological outcomes, are examples of areas that remain poorly explored (Gascon et al., 2015). Despite concerns raised by researchers regarding the methodological limitations and lack of consistency in the results of some nature-health research (Lee and Maheswaran, 2011, Hartig et al., 2014, Gascon et al., 2015), studies into human interactions with nature are generally supportive of the premise that natural environments have a more favorable effect on human psychological health than do urban or built environments, whether experienced indirectly or directly through visual (Kaplan and Kaplan, 1989, Ulrich et al., 1991), auditory (Alvarsson et al., 2010, Annerstedt et al., 2013), or olfactory contact (Tsunetsugu et al., 2010). People living in urban areas with more green space are often found to have better mental health and perceived general health than people living in urban areas with less green space, even when controlling for a range of extraneous factors such as income and marital status (Beyer et al., 2014, de Vries et al., 2003). Studies suggest that visiting or viewing natural settings may improve concentration in children with ADHD (Taylor and Kuo, 2009); reduce anxiety in hospital patients (Beukeboom et al., 2012); minimize perceived pain and discomfort (Diette et al., 2003); restore cognitive function (Hartig et al., 1991); and facilitate recovery from stress (Ulrich et al., 1991, Beil and Hanes, 2013). Furthermore, contact with nature has been associated with lower frustration (Aspinall et al., 2015); increased happiness (MacKerron and Mourato, 2013); improved mood and self-esteem (Barton and Pretty, 2010); and faster recovery from surgery (Ulrich, 1984). For these reasons and more, it is not surprising that the presence of natural space in urban areas is considered by many to be a form of ‘upstream health promotion’ that has the potential to positively influence human wellbeing on a population-wide scale (Maller et al., 2006).

In spite of a growing body of research documenting the importance of nature to human health, natural space in many urban areas is decreasing (McDonald et al., 2010, Sivam et al., 2012). The demand for infrastructure to meet the needs of growing urban populations is often met through the development and modification of natural areas. This is of great concern, as a lack of green space reduces opportunities to experience nature, and may be impacting the mental health of urban inhabitants (Bratman et al., 2015). In Australia, urban residents are more likely to suffer from high or very high psychological distress (Australian Bureau of Statistics, 2011) and face a higher risk of developing substance use disorders than rural residents (Cantwell et al., 2012). The story is similar in other western nations such as Great Britain, where people residing in cities have been found to have poorer mental health than their rural counterparts (Paykel et al., 2000). Some researchers have estimated that urban inhabitants face a 21% greater risk of developing an anxiety disorder, and a 39% greater risk of developing a mood disorder than rural inhabitants (Peen et al., 2010). The proportion of the global population residing in urban areas is expected to continue rising for decades to come (The United Nations, 2014), and with this shift, we can expect to see continued increases in psychological disorders such as chronic stress, anxiety and depression. Providing planners with information about the attributes of natural environments that optimize recovery from stress and fatigue may therefore contribute to improving quality of life for many people.

3.2.2. A healthy urban environment

Increasing the amount of natural space in urban areas, or 'neighborhood greening' has been proposed as one possible approach to helping create a healthier living environment for urban inhabitants (Beyer et al., 2014). However, some studies indicate that simply having more green space in urban settings may be ineffective at improving human health (Richardson et al., 2012) or promoting greater use of natural environments (Francis et al., 2012). After decades of research that followed a largely dichotomous 'urban' vs. 'natural' environments approach, many scholars have noted there is a dearth of information regarding the actual attributes of natural environments that are required to facilitate psychological benefits (Frumkin, 2003, Nordh et al., 2009, Keniger et al., 2013). More recently, researchers have begun focusing on the

'micro' features of natural settings that might promote greater use and improve mental health outcomes in urban areas. As opposed to 'macro' features, which typically include landscape-scale elements such as the quantity of green space in a given area, or its proximity to people's homes, 'micro' features refer to site-specific differences between green spaces that might encourage use or enhance visitor experiences. Such 'micro' features may include particular vegetation types, opportunities to view wildlife, specific landscape elements such as creeks, and physical amenities such as trails or exercise equipment. In Perth, Western Australia, Francis et al. (2012) used the Public Open Space Tool (POST) to assess park quality, considering 'micro' variables such as walking trails, shade, birdlife and the presence of water as contributors to park quality, based on the opinion of an expert panel. Their study concluded that the quality of green space in one's neighborhood was more important to one's mental health than the quantity of green space or the frequency with which one visited it. Other studies have found that different types of urban green space facilitate different types of health benefits (Brown et al., 2014); that the psychological benefits of contact with nature may be positively influenced by biodiversity (Fuller et al., 2007, Carrus et al., 2015) or perceived biodiversity (Dallimer et al., 2012); and that restorative outcomes may be associated with naturalness in pocket parks (Nordh et al., 2009). In this study, we aimed to identify the types of natural environments and 'micro' attributes that are most important to South Australians. Using self-reported 'favorite places' as exemplars of restorative environments, we also explored the relative importance of the key components central to Attention Restoration Theory (R. Kaplan & Kaplan, 1989).

3.2.3. Restorative experiences and favorite places

The restorative benefits of natural environments are widely documented (e.g. Kaplan and Kaplan, 1989, Hartig et al., 2003), and have been a prominent feature of nature-health research for decades. Restoration refers to the psychological and/or physiological recovery one experiences during exposure to certain environments, and is most commonly explained by two dominant theories in the field: Attention Restoration Theory (ART) and Stress Reduction Theory (SRT). The two theories attempt to describe the mechanisms by which natural environments have a positive

effect on human wellbeing, with ART concerning recovery from cognitive or attentional fatigue (Kaplan and Kaplan, 1989), and SRT concerning recovery from stress (Ulrich, 1983). In nature-health research, ART and SRT have commonly been regarded as "complementary perspectives that focus on different aspects of the restorative process" (Joye and van den Berg, 2013, p. 59).

According to ART, an environment is more likely to be restorative if it exhibits four characteristics: (1) it allows for a feeling of 'being away' by being geographically and/or psychologically distant from the daily hassles of life and the sources of attentional fatigue; (2) it has sufficient 'extent' and scope to allow for an immersive experience; (3) it is able to offer 'compatibility' with the intentions/needs of the person experiencing the environment; and (4) it provides 'soft fascination' to catch one's attention without cognitive effort. As opposed to fascination in general, which may be derived from stimuli such as car accidents or violent scenes, settings that are rich in soft fascination – such as "the play of light on foliage" (Kaplan & Kaplan, 1989, p. 193) – capture our involuntary attention in a non-threatening way, allowing the mind to wander and our attentional capacity to replenish. Generally, these features are more characteristic of natural rather than urban or built environments (Kaplan and Kaplan, 1989).

Natural environments are frequently cited as being 'favorite places' of participants in restoration and place attachment research (Korpela and Ylen, 2007, Newell, 1997). Favorite places are those locations that individuals have formed an "emotional tie or affective bond" with (Korpela et al., 2009, p. 96). They are places that one might "value being in more than any other place" (Korpela et al., 2001, p. 579), or would choose to protect from "damage or destruction" above all others (Newell, 1997, p. 500). It has been suggested that this emotional bond forms because favorite places facilitate self-regulation, the act of mentally processing the psychological influences of external factors such as emotionally arousing situations (Korpela and Ylen, 2007) or sensory stimuli (Korpela, 1992). Self-regulation occurs when one applies mental, social, physical, or environmental strategies to help regulate their feelings and maintain their sense of self, or self-esteem. As restorative experiences may involve

"reflection on oneself and one's place in the world" (Korpela and Hartig, 1996, p. 222), interacting with natural environments can be considered a form of environmental self-regulation (Korpela and Ylen, 2007). People are known to actively seek out natural environments when they are in need of restoration (e.g. Irvine et al., 2013) and preferences for nature are found to be higher in individuals who are in greater need of restorative experiences (Hartig and Staats, 2006). According to Korpela et al. (2001, p. 573) "places that a person can rely on for restorative experiences are thus more likely to be places for which attachments develop over time and that in turn come to figure in place identity." Tellingly, individuals prescribed with visiting their favorite places have been shown to experience significantly stronger restorative outcomes than individuals visiting other places (Korpela et al., 2009). For this reason, favorite places have been used as a "window" into restorative environments in previous research (Korpela et al., 2008, p. 637).

3.2.4. Favorite places and environmental attributes

As 'exemplars' of environments used in self-regulation and restorative experiences (Korpela and Hartig, 1996), an evaluation of the types of natural environments people consider to be their favorite places is relevant, as is identifying the elements people use to explain why an area is favored. A search for "favorite place" or "favourite place" literature published in peer reviewed journals over the past 30 years revealed only 10 articles. The majority of these articles were conducted by Korpela and associates, and have been primarily based in Europe. Two studies took place in the United States (Newell, 1997, Korpela et al., 2001), one of which also collected data in Ireland and Senegal (Newell, 1997). No explicit "favorite place" research appears to have been conducted in Australia. Each article was assessed to identify the types of environments and environmental characteristics that respondents valued most highly (Table 3.1).

Table 3.1. Favorite place types and features identified in previous research.

Author/s	Favorite Place Types	Method of identifying favorite places	Consideration of ART	Consideration of attributes	Study Population
(Korpela, 1989)	Focus was on feelings created by the environment, rather than the physical characteristics of it. However, features frequently described by respondents, included: homelike, peaceful, secure, comforting, huge, indomitable, powerful, beautiful, silent, rugged, pleasant smell of wood, and colorfulness and greyness and ugliness at the same time.	Survey and essay. Survey: the 9 and 12-year old students answered 10 verbally delivered questions, asking them to describe their favorite place and why they like to visit it. Essay: the 17-year old students were asked to write an essay about their favorite place, its features, the feelings it gives them, and the mood they are in when they visit it.	No	Yes	Students aged 9, 12, and 17 years old, in and near Tampere, Finland.
(Korpela, 1991)	Most common types of favorite places were: private homes (39%), restaurants/downtown (16%), natural settings (14%), sport facilities (14%), clubs (7%), and 'other', such as a car or motorcycle (10%)	Essay: in first study, respondents were asked to write an essay on their favorite place, explaining why it was important to them and what experiences and feelings they had there. In second study, participants were asked to write an essay on their experiences in their favorite place, focusing on the situations and feelings that motivated them to go there.	No	No	Students aged 17-18 years, near Tampere, Finland.
(Korpela, 1992)	Most common types of favorite places were: private homes (39%), natural settings (15%), restaurants/downtown (15%), sport facilities (13%), clubs (7%), and 'other', such as a car or motorcycle (7%)	Essay: students were asked to write an essay about their favorite place, describing what sort of place it was, why it was their favorite place, and what personally important thoughts, feelings or experiences they have had there.	No	No	Students aged 17-18 years, near Tampere, Finland.
(Korpela and Hartig, 1996)	Using a list of characteristics, respondents indicated the extent to which they were present in their favorite places. The most frequently reported characteristics were: beautiful views (83.3%), sunlight (83.1%), the presence of water (73.1%); and the presence of personal	Survey: respondents were asked to evaluate 7 settings, including a 'favorite' and 'unpleasant' place in their life, by completing the Perceived Restorativeness Scale (PRS) and ZIPERS.	Yes	Yes	Students from the University of Tampere, Finland. Aged

	belongings (56.4%).				19-46 years.
(Newell, 1997)	Natural sites in general were the favorite places of respondents. Ten place type categories ranked according to frequency: (1/2) 'personal bedroom/belongings' were equal with 'outdoors, nature, the Earth'; (3) beaches/coastline; (4) family home and surroundings; (5) built environment, pubs, streets; (6/7) woods/forests were equal with countryside/fields; (8) mountains; (9) recreation areas/parks; (10) rivers, lakes and ponds.	Survey: open-ended responses to a question about their one favorite place "to save from damage or destruction."	No	No	Psychology and sociology students from universities in: USA, Ireland and Senegal. Aged 18-45 years.
(Korpela et al., 2001)	Largest proportion of favorite places (48%) were natural spaces, followed by residential sites (19%); geographic areas such as a country or city (16%); leisure settings such as amusement parks and zoos (5%); and school /university settings (4%).	Survey: open-ended responses to questions about their favorite place. Respondents asked to imagine being in their favorite place, "that one place in which you have most enjoyed spending time, or that you have valued being in more than any other place. Perhaps you view this place as being particularly significant in your life." Also completed the (PRS).	Yes	No	Psychology students from Berkeley, United States. Aged 17-47 years.
(Korpela and Ylen, 2007)	Natural sites favorite places of 51% of respondents. No figures provided for place types, but the most frequently mentioned favorite natural places were nearby parks, woods, and seashores.	Survey: open-ended responses to the question: "Think about your residential area for a moment. What is your *favorite* place within the area? This place may be located indoors or outdoors."	No	No	Residents of four residential areas in Helsinki, Finland. Average age 40 years.

(Korpela et al., 2008)	Natural sites favorite places of majority of respondents. Sixteen favorite place types were grouped into five main place types. Ranked according to frequency: (1) extensively managed natural areas, e.g. woods, forests, meadows; (2) built-up green spaces, e.g. parks; (3) waterside environments, e.g. beaches and harbors; (4) exercise and activity/hobby areas, e.g. playgrounds and sports ovals; (5) indoor and outdoor urban/built areas.	Survey: rating the personal significance of 16 types of settings in the local area. Selecting one type in which their favorite place is represented, and describing that place. Descriptions used to categorize place types.	No	No	Residents of Helsinki and Tampere, Finland. Aged 15-75 years.
(Korpela and Ylen, 2009)	Natural sites favorite places of majority of respondents. Looked at consistency of re-selecting same type of favorite place over a 10-month period. Most frequently selected favorite places in both surveys were small-scale natural state areas, beaches and harbor areas, and large forest areas.	Survey: rating the personal significance of 16 types of settings in the local area. Selecting one type in which their favorite place is represented, and describing that place. Descriptions used to categorize place types.	No	No	Residents of Helsinki and Tampere, Finland. Aged 15-75 years.
(Korpela et al., 2010)	Natural sites favorite places of majority of respondents. Sixteen favorite place types were grouped into five main place types. Ranked according to frequency: (1) extensively managed natural areas, e.g. woods, forests, meadows; (2) built-up green spaces, e.g. parks; (3) waterside environments, e.g. beaches and harbors; (4) exercise and activity/hobby areas, e.g. playgrounds and sports ovals; (5) indoor and outdoor urban/built areas.	Survey: rating the personal significance of 16 types of settings in the local area. Selecting one type in which their favorite place is represented, and describing that place. Descriptions used to categorize place types.	No	No	Residents of Helsinki and Tampere, Finland. Aged 15-75 years.

In general, natural settings were the most commonly identified favorite places, with two exceptions (Korpela, 1991, Korpela, 1992). Overall, there was great variation in the types of natural environments reported as favorite places, which may be a result of the classification systems used in different studies. Only two studies (Korpela and Hartig, 1996, Korpela, 1989) explored the attributes of favorite places. As shown in Table 3.1, 'beautiful views' and 'sunlight' were the most frequently mentioned attributes of favorite places in Korpela and Hartig (1996), and in Korpela (1989) responses such as 'homelike' and 'peaceful' featured frequently. Two studies also related responses back to the components of restorative environments by using the Perceived Restorativeness Scale (PRS) (Korpela and Hartig, 1996, Korpela et al., 2001). Interestingly, in both of these studies, fascination was found to be the least important component of restoration in favorite places.

3.2.5. The importance of healthy natural environments

Fascination is a central component of restorative experiences (Kaplan, 1995), and the likelihood of restoration is thought to be greater in natural environments that exhibit more fascinating qualities (Nordh et al., 2009). Fascination has been related to concepts such as naturalness (Nordh et al., 2009, Van den Berg et al., 2014) and wildness (Annerstedt et al., 2012), which may also relate to ecological quality (Winter, 2012). As fascination refers in part to the ability of an environment to capture and hold one's attention, and natural scenes are considered to "contain many more fascinating features or elements than urban environments" (Joye et al., 2013, p. 3), it stands that dynamic environments containing a greater variety of plant and animal species might thus generate greater fascination. Indeed, visitors to high biodiversity environments have been found to derive a greater level of psychological benefit than visitors to low biodiversity environments (Fuller et al., 2007, Carrus et al., 2015), although this was not directly linked to fascination by the researchers.

There have been repeated calls for research that provides insight into the specific features of natural environments that are required for the attainment of psychological benefits (e.g. Frumkin, 2003, Bratman et al., 2012, Keniger et al., 2013, Velarde et al., 2007). There is a dearth of practical information on this topic available to park agencies tasked with balancing human and environmental benefits in parks and protected places. Furthermore, studies into the health benefits of natural environments have been almost exclusively anthropocentric in nature, and have paid little attention to the health of ecosystems (Lang and Rayner, 2012, Jorgensen and Gobster, 2010). As environmental health and mental health in many urban areas continues to deteriorate, research that prioritizes the health of both human beings and the natural environment will be of increasing importance (Parks Victoria, 2015). As exemplars of restorative, health-giving environments, we believe investigating perceptions of 'favorite places' and the natural micro features that people use to explain their connection to these settings will provide valuable information for urban planners seeking to optimize the health benefits of nature. Using previous restoration research as a means to classify responses, we also sought to explore how Australians compared to their European and North American counterparts, in terms of the relative importance they placed on the four components of restorative environments according to Attention Restoration Theory. The three questions that guided our inquiry were:

1. Which types of natural environments do South Australians value most highly?

2. What attributes of natural 'favorite places' do individuals take notice of and use to explain their connection to these places?

3. Does the relative importance of the four Attention Restoration Theory components in Australian 'favorite places' reflect those of European and North American favorite places?

3.3. Methods

3.3.1. Study setting

The study was conducted in South Australia, a state that spans an area of 984,377 km² and contains a population of 1.7 million people (Australian Bureau of Statistics, 2015). The size and diverse landscapes within the state, described as varying "from rugged outback wilderness and desert to scenic mountain ranges and a coastline that stretches more than 3,700 km" (South Australian Government, 2014, p. 1), made it an ideal location to examine the attributes that are associated with favorite landscapes. The state's population resides primarily in the capital city, Adelaide (77%), but also in large regional centers, and hundreds of small country towns. The study surveyed residents across the State as a whole, to learn more about 'favorite places' within South Australia.

3.3.2. Data Collection and Procedure

Data collection took place between 1 September and 30 November 2014, using an online questionnaire. The questionnaire consisted of 19 questions exploring participants' use of public and private green spaces, their memories of interacting with nature as children, the centrality of nature in their lives today and a set of demographic questions. The questionnaire also contained two open-ended questions, which form the focus of the present paper. Respondents were asked "what are your favorite outdoor places in South Australia?" and "What is it that you love most about these places?"

Following approval by the University of South Australia Human Research Ethics Committee, the survey was launched on a specially designed webpage that included short human interest stories about outdoor experiences, as well as podcasts of a six-week radio program titled "Operation Outdoors". The survey was kept open for 6 weeks after the end of the radio program. The webpage was hosted by ABC Adelaide, who in 2015 held a 12.5% share of South Australia's radio audience; the second most popular radio station in the State (CRA, 2015). As part of the Australian Broadcasting

Commission (ABC), ABC Adelaide's existing website received high traffic and we were confident the popularity of the company's website would lead some people to the Operation Outdoors page independent of promotion. In addition, the page was promoted during the six-week program of bi-weekly 'talkback radio' sessions hosted by two of the authors. The radio sessions focused on an eclectic mix of topics related to the natural environment. Broadly speaking, the radio segments were conversations encouraging people to reminisce about outdoor experiences and the value of those experiences, rather than conversations about specific places. Half of the sessions discussed historical perspectives of green spaces, and included topics such as "A Spring in My Step", "The Value of Parklands" and "Drunkenness or Civilization: the Story Behind our Gardens". This novel method of recruitment was trialed due to the increasing difficulty of engaging the public to complete surveys. Given the indirect method of participant recruitment for this convenience sample, a traditional study response rate cannot be calculated. Participation in the study was voluntary, and no incentive was provided to respondents.

To investigate potential bias, we examined the timing of questionnaire completions, and while there was a peak in responses on the day of each radio session, there was steady traffic throughout the week, and also during the six weeks after the program had finished. Audio recordings of each radio session were transcribed, allowing us to examine potential bias in self-reported "favorite places" that might be associated with mentioning specific natural sites during the radio segments. Notably, in the week the radio hosts discussed the history of gardens there were more mentions of the Botanic Garden (17.5% greater that week), compared to the other 11 weeks. This should be taken into consideration when viewing the results.

3.3.3. Overview of Respondents

In total, 447 people completed the questionnaire. The majority of respondents were female (65.7%), mature aged (range: 14 to 81 years; mean 52 years), and highly educated (53.66% with a bachelor degree or higher), as shown in Table 3.2. Commensurate with this, the majority of respondent households contained mature/older adults with no children (55.3%, i.e. mature singles and older couples with no children at

home). According to census data (Australian Bureau of Statistics, 2015) the demographics of the study sample are not necessarily reflective of the South Australian population, which has a lower proportion of females (50.7%); a younger median age of 39 years; a greater number of households with children (57.8%); and far fewer people with university degrees (14.4%). This is likely a result of the methods used to recruit participants, as both the radio station, and the particular program which included discussions and interviews about the environment and our historic use of it, was more likely to attract an older, more highly educated audience.

Table 3.2. Overview of respondent characteristics (*n* = 447)

Demographic variable	**Option**	**Percentage**
Gender	Female	65.7
	Male	34.3
Education	Bachelor degree	30.49
	Postgraduate degree	23.17
	Some undergraduate tertiary	14.02
	Secondary school	13.72
	Vocational/technical training	12.50
	Primary/some secondary school	6.10
Lifecycle	Older couple, no children at home	34.0
	Mature single	21.3
	Middle family (youngest child 6-15 years of age)	12.3
	Mature family (all children over 15 years of age)	10.2
	Young single	9.3
	Young family (youngest child less than 6 years of age)	7.7
	Young couple, no children	5.2

3.3.4. Analysis

Participants' favorite places and demographic data were analyzed using SPSS® software to calculate descriptive statistics such as frequencies and means. Participants' responses about why they loved particular places were coded in QSR Nvivo® using inductive content analysis. Directed content analysis was used to examine the relative importance of the four Attention Restoration Theory components in Australian 'favorite places'. The two procedures are explained in the following sections. Similar to Irvine et al.'s (2013) study, where multiple answers were provided by respondents, they were treated as separate, individual statements.

3.3.4.1. Popular types of natural favorite places

Favorite places were initially grouped by name so that we could ascertain which favorite places were shared amongst multiple respondents. This process resulted in 241 unique locations across South Australia. These favorite places were then classified using a modified National Recreation and Parks Association (NRPA) park typology (Mertes and Hall, 1996) to identify the types of natural environments that are favored by the public. The NRPA classification system primarily differentiates parks according to their size, location, and use. However, given the non-spatial method of data collection in the present study, we made several modifications to the park typology that we considered to be more locally indicative of how the parks were used. These changes – such as combining neighborhood, mini, and community parks – are shown in Table 3.3, which outlines the eight classifications used in the study and provides a rationale for changes made to the original NRPA typology.

Table 3.3. The modified NRPA park typology used to classify “favorite places.”

Classifications used in this study	Description	NRPA classifications	NRPA size and location guidelines	Modification rationale
Community park	Variable size and location. Recreational green spaces, not dedicated solely to conservation or sports	Community park	Usually between 30 and 50 acres, ½ mile to 3 mile distance	Incorporated neighborhood, mini-parks and large urban parks based on their similarities in intended use, as places of passive and active recreation
School park	School-owned green spaces, not always publically accessible. Variable size, location determined by school	School park	Variable size, location determined by school	No change
Sports park	Sports complexes and ovals, location and size variable	Special use, Sports complex	Special use – size variable, location variable Sports complex – usually a minimum of 25 acres with 40-80 acres optimal, strategically located	The study sites were specifically sports fields
Nature park	Natural resource areas, for example National Parks – size variable, location depends on availability and opportunity	Natural resource areas	Size variable, location depends on availability and opportunity	The new terminology is to clarify that these areas are parks
Linear park	Greenways and trails – location variable	Park trails, Connector trails	0.5 miles per 1000 (1983 NRPA standard), location variable	More precise terminology has been used because the connector trails in this study were linear parks
Botanical gardens and arboreta	Formal botanical gardens, zoos and arboreta dedicated to the display and study of different species	N/A	N/A	This classification was added to differentiate these green spaces based on their intended use as places of recreation, learning, and the public display of species

Beach or coastal park	Beaches – Size variable, location depends on availability and opportunity.	N/A	N/A	Beaches were differentiated from other natural parks, based on their distinct natural features
Private green space	Privately owned gardens and back yards	N/A	N/A	Although not a type of park, private green space represented a substantial number of favorite places and warranted differentiation from public parks
		Neighborhood park	5-10 acres optimal, ¼ to ½ mile distance	Neighborhood parks were classified as community parks because they are both managed by local councils, and tend to have more similarities than differences in terms of services, facilities and use patterns.
		Mini-park	Between 2500 sq. ft. and one acre, less than ¼ mile in residential setting	Mini-parks were classified as community parks because they are both managed by local councils, and tend to have more similarities than differences in terms of services, facilities and use patterns.
		Large urban park	Usually a minimum of 50 acres with 75 or more acres optimal, usually serves entire community.	Large urban parks were classified as community parks because they are both managed by local councils, and tend to have more similarities than differences in terms of services, facilities and use patterns.

3.3.4.2. Loved attributes of natural favorite places

To identify the loved attributes of respondents' favorite places we used an inductive approach to content analysis, whereby we avoided using preconceived categories and instead allowed the categories and their names to flow from the data as we explored it (Hsieh and Shannon, 2005). Although the majority of characteristics identified by Korpela (1989) and Korpela and Hartig (1996) were also in our final word lists, we did not confine our content analysis to the items used in those studies, for several reasons: 1) Lack of background knowledge as to how Korpela and Hartig (1996) derived the initial list of 16 attributes that they provided their respondents with; 2) We believed a list of 16 attributes was unlikely to be sufficiently exhaustive to accurately reflect the experiences of hundreds of respondents in hundreds of different locations; 3) Some of the items used in the previous studies were not suitable for a South Australian context, such as 'lake ice' (Korpela and Hartig, 1996); 4) Korpela's (1989) focus was on feelings created by favorite places, and as a result he paid little attention to the attributes he identified as being important, such as 'greyness' and 'ugliness', but rather the feelings they conjured; and lastly, 5) There was little consistency between the two previous studies in terms of the attributes they identified, which further encouraged us to err on the side of caution and follow an inductive approach. Whilst conducting the inductive content analysis we believed there was some risk of bias, in that we might misinterpret certain statements simply by restricting them to a single node. To minimize this potential bias, the researchers undertook the first step together, and when necessary, allowed responses to be coded into multiple nodes to avoid making assumptions about intended meanings.

An initial sample of one hundred responses was read by the researchers, who agreed there were three broad themes running through the data, namely: descriptions of the physical environment, recreational activities that occurred in favorite places, and the benefits people derived or desired from them. Following this early analysis, we used Moore and Driver's (2005b) synthesis of benefit research to strengthen category formation, and using the complete set of responses, highlighted all occurrences in which we believed the respondent was referring to an aspect of the biophysical setting, an

activity, or a benefit. Discrepancies were overcome through discussion and the establishment of rules that enabled similar phrases or words to be categorized consistently. Following the extraction of all setting-, activity- and benefit-related responses, a similar approach using multiple researchers to triangulate results was used in further analysis and coding into sub-nodes. The nodes used in the study are shown in Table 3.4, along with examples of sub-nodes and participant responses. A complete list of sub-nodes can be obtained from the authors upon request.

Table 3.4. The nodes used in inductive content analysis during the study.

Domain	Nodes	Example sub-nodes	Example responses
Setting attributes	Natural attributes	Birds Other fauna, wildlife Plants, vegetation, flora Flowers, orchids, blossoms Aesthetics, beauty, views Quiet, peace, tranquillity, silence Natural processes, seasonal changes Biodiversity and diversity Creeks, rivers, lakes Beach, ocean, sea Sounds and smells of nature Rocks, cliffs, soils, geology Mountains	"Tall trees attracting native birds, hearing and watching bird activities… Seeing the buds burst into colour, smelling the flowering creepers and plants, nature's perfume, habitat for insects and butterflies…" † (Natural attributes; low intensity activities) "Birds and plants are always interesting." "It's full of native critters; creek systems, caves, waterfalls, billabongs, cliffs, beaches…" "The cliffs and hills are a myriad of colours and the views from the top are fantastic. I regularly watch many species of birds including kestrels, peregrine falcons, white-breasted sea eagles, pacific gulls, cormorants, terns, hooded plovers, etc.

			Brown snakes, lizards, dolphins, NZ fur seals and many other critters, both indigenous and (sadly) exotic." † (Natural attributes; low intensity activities)
			"I enjoy…the geology, the wildlife, the creeks and rivers. Any weather and season there is always something new."
			"…take in the sights, smells and sounds - it is a very sensory experience for me."
	Human-managed attributes	Accessibility and proximity	"Close to home, paths allowing easy access."
		Picnic and BBQ facilities	
		Swimming pools	
		Seating	"Lots of hiking tracks to walk. Facilities like BBQs..." † (Human-managed attributes; moderate intensity activities)
		Art and sculptures	
		Toilets	
		Walking and cycling trails	"A mixture of special plants, garden art and sculptures..." † (Human-managed attributes; natural attributes)
		Park maintenance, cleanliness	
		Playground or play space	
			"The athletics field is well maintained."
			"There are places I like to have coffee, toilets, children's playground, dog poo bags, barbecues, anything you might desire." (Human-managed attributes; low intensity activities)
			"Kept tidy and clean, convenient, traffic is minimal and slow…"
Activities	Low intensity activities	Bird watching	"I can watch the birds eating insects and nectar, scratching in the dirt and collecting material to build nests." † (Low intensity
		Picnics/dining	

		Sitting	activities; natural attributes)
		Fishing	
		Reading	
			"A good place to read books and eat a picnic lunch…"
			"…Sitting in the sun, reading quietly, relaxing and feeling the grass beneath my feet." † (Low intensity activities; natural attributes, personal benefits)
	Moderate intensity activities	Walking	"Hiking, geocaching, kayaking…"
		Gardening	
		Cycling	"I ride my bike from Paradise to the sea - such fun on the downhill run, though a lift home helps."
		Swimming	
		Kayaking	
			"I love getting my hands in the dirt and gardening"
			"I love going there for a swim on a hot summer's day."
	High intensity activities	Sport	"The ability to have a run around or a kick of the footy."
		Running/jogging	
		Mountain Biking	
			"Good training grounds for running."
			"Fantastic mountain bike ride up to Cleland..."
Benefits	Personal benefits	Solitude, privacy, escape crowds or city	"A chance to escape from a busy and scheduled day-to-day life without phones and screens."
		Discovery, exploration, learning	
		Rest and relaxation	"A sense of being outside the city, personal restoration, exercise."
		Improve mood or happiness	
		Spiritual or personal values,	

	connection	"Still so much to be explored and discovered…"
	Nostalgia and memories	
	Physical fitness and exercise	
	Independence, freedom, autonomy	"…The freedom to explore different footpaths and get lost but always feel safe." † (Personal benefits; human-managed attributes)
	Feeling Safe	
	Awe, wonder, marvel	
		"Flinders is a spiritual home - wild, silent, magnificent. I connect with God and the traditional owners." † (Personal benefits; social benefits; natural attributes)
		"…Strong childhood memories, so will always love."
		"…Sense of awe and wonder they engender. Supports spiritual development… De-stress… Re-energise... Development of wisdom through just being there."
Social benefits	Family bonding	"…Many afternoon teas shared there with family and friends." † (Social benefits; low intensity activities)
	Be with friends	
	Neighbourhood relations	
	Teaching, leading, sharing skills	
		"I more easily chat to neighbours if I am in the garden trimming or weeding, so neighbourly relations develop naturally." † (Social benefits; moderate intensity activities)
		"Teaching my kids about nature and instilling in them an appreciation and respect for nature." † (Social benefits; environmental benefits)
Environmental	Environmental stewardship	"We feel ourselves to be stewards of this

benefits	land and the ones to look after it…"
	"I am a bush Carer with Trees For Life there. This means that I have a great emotional attachment to it, what I do by planting trees and removing introduced weeds from it greatly helps local native plant species return." † (Environmental benefits; personal benefits; natural attributes)
	"Being part of preserving the biodiversity of this area is a huge buzz. Saving the flora and fauna for future generations is very satisfying…" † (Environmental benefits; natural attributes)

† Denotes an item that was coded into multiple nodes. The nodes are provided in parentheses following the quote.

3.3.4.3. Relative importance of ART components in natural favorite places

The third objective of the study was to explore how participants' personal descriptions of their favorite places related to the four components of restorative environments according to Attention Restoration Theory (ART), i.e. being away, fascination, extent, and compatibility. To do this, we used a directed approach to content analysis, where existing research about restorative environments helped to determine the initial coding scheme (Hsieh and Shannon, 2005). To begin, we compiled lists of words that have been used in previous restorative environments studies to describe the four components of ART (e.g. Kaplan, 1995). Many words and phrases were adopted from the 'Perceived Restorativeness Scale' (PRS) developed by Hartig and associates (Hartig et al., 1997). After an initial read-through of the responses, we were able to add words and phrases to the lists, which we felt were reflective of particular ART components. At times we used a thesaurus to identify related words, or in the case of 'chaos' from the PRS, to identify antonyms. The use of a thesaurus also helped the researchers to reach consensus about which component of ART particular words related to.

As with the inductive coding used to identify loved attributes of favorite places, when necessary, we again allowed responses to be coded into multiple nodes. In doing so, we acknowledged that some responses, such as particular environmental attributes, might be correlated with multiple items. For example, using the PRS, (Scopelliti et al., 2012) found that biodiversity was correlated with being away, compatibility, extent, and fascination. It is generally agreed that an interest in observing natural elements is consistent with the construct of fascination, rather than compatibility (e.g. 'many interesting things' and 'looking at the surroundings' from the PRS (Hartig et al., 1997) and 'living things' from Joye et al. (2013) – see Table 3.5). Thus, it seems that a significant relation between biodiversity and all four ART components, e.g. in Scopelliti et al. (2012), could be due to a method bias associated with the PRS as discussed by Joye et al. (2013, p. 2) – i.e. correlations between items may simply be "due to employing one common method of measurement for all these items). Therefore in the present study, unless respondents explicitly referred to engaging in an activity dependent on particular natural features, such as "bird watching", references to natural elements (including biodiversity) were coded solely as fascination. The word lists are provided in Table 3.5.

Table 3.5. Word lists used in directed content analysis.

Component	Associated words, phrases and concepts	Source	Example responses
Being away	Being away	(Kaplan and Kaplan, 1989)	"Vast natural spaces that seem far away from man made structures… Far away from traffic and modern life…" † (Being away; extent)
	Getting away	(Kaplan, 1995)	"…Once you are there it feels like "getting away" from city life just for a few hours."
	Distance from: daily hassles, work, routines, ordinary aspects of life	(Hartig et al., 1997)	"Being able to switch off from the regular stresses of life."
	Escape unwanted distractions; an escape experience	(Hartig et al., 1997)	"Being outside away from computers, lights, advertising… Peace and quiet."
	Movement to another setting or another situation	(Hartig et al., 1997)	
	Geographical or psychological distance	(Hartig et al., 1997)	
	Having a break; taking a break	(Hartig et al., 1997)	
	Rest and relaxation	Authors	
	Private; privacy	Authors	
	Getting away from: the city, traffic, noise	Authors	
	Getting outside, getting some fresh air	Authors	
	Enjoy the peace and quiet	Authors	
		Authors	

Fascination	Fascination	(Kaplan and Kaplan, 1989)	"I enjoy watching the plants and flowers grow. I also enjoy watching the wildlife about the place (lizards, butterflies, spiders etc.). Just going bird watching, the birds are glorious." † (Fascination; compatibility)
	Beauty	(Korpela et al., 2001)	"…I have a feeling of calm and 'slowing down' when I'm observing small things close up - like insects or flower parts or the behaviour of birds - it's these times when I can focus on the now without other thoughts crowding in." † (Fascination; being away)
	Exploration	(Hartig et al., 1997)	"All are home to a myriad of birds, animals and little creatures…"
	Fascinating qualities	(Hartig et al., 1997)	"…I also enjoy the life that crops up boldly by itself - like the lichens on the footpaths and roofs, the single little grass that lives in a tiny hole in the footpath, the small bluetongue poking its head out of an unruly garden, the native cockroaches quietly going about their business in the creeper in a tucked-away local park..."
	Many interesting things	(Hartig et al., 1997)	"…The difference in the water whenever one looks at it, depending on the weather."
	Getting to know the place better	(Hartig et al., 1997)	
	Explore and discover	(Hartig et al., 1997)	
	Looking at the surroundings	(Hartig et al., 1997)	
	Living things	(Hartig et al., 1997)	
	Changing colours, seasonal changes	(Joye et al., 2013)	"…The constant change of colour of the paddocks, the blossom and flowers on the trees, the lambing season, the change in the appearance of sheep after shearing, the noise of the guinea fowl, geese, chooks, pheasants."
	Constant change, e.g. clouds, flowing rivers	(Joye et al., 2013)	"Mostly the sensory pleasure they bring."
	Variety of plants and animals	(Joye et al., 2013)	
	Sounds and smells	Authors	
	Plants, animals, natural features	Authors	
		Authors	

Extent	Being in a whole other world	(Kaplan, 1995)	"The wide open spaces…"
	Provides enough to see, experience, and think about	(Kaplan, 1995)	"…Wander in another world…just escape..." † (Extent; being away)
	Ability to make sense of the environment	(Hartig et al., 1997)	"In every place and every time you see something unique and memorable." † (Extent; fascination)
	Distraction	(Hartig et al., 1997)	
	Order, harmony (opposite of 'chaos' from PRS)	(Hartig et al., 1997)	"I love these spaces because there is lots of space to do whatever you want…" † (Extent; compatibility)
	There is a lot going on	(Hartig et al., 1997)	
	Large enough to explore	(Bodin and Hartig, 2003)	
	Space; wide open spaces; lots of space	Authors	
	Big enough to get lost	Authors	
Compatibility	Feelings of belonging	(Korpela et al., 2001)	"The peace that being in this place brings my soul."
	Match between inclinations/activities and environment	(Hartig et al., 1997)	"Halbury Parklands: The love of my childhood life. My playground and education. The scrub and me were/are one! At 71 years of age I return to it annually to 'ground' myself, to reconnect with what is most important to me…"
	I can do things I like here	(Hartig et al., 1997)	
	The sense that I belong here	(Hartig et al., 1997)	"I like the wide open spaces and how you can play soccer and ride a bike in the same place." † (Compatibility; extent)
	Sense of oneness with the setting/the environment	(Hartig et al., 1997)	
	Being here suits my personality	(Hartig et al., 1997)	"…Port Elliot is a 'homing' place for me as I spent many, many weeks as a child there in the caravan park. Even though I go only rarely now, when I do, I have a calm feel, Rooted is the best description."
	Enjoy this place	Authors	
	Reference to activities: walking, picnicking, etc.	Authors	"Provides a sense of place and connectedness..."
	Time with family and friends	Authors	

	Near where I live; proximity to my home	Authors
	Safety; feel safe here	

† Denotes an item that was coded into multiple nodes. The nodes are provided in parentheses following the quote.

3.4. Results

3.4.1. Popular types of natural favorite places

Respondents were asked the question, “What are your favorite outdoor places in South Australia?” A total of 1022 favorite places were provided, with respondents generally listing between one and three favorite places. After grouping the favorite places by name, this list was reduced to 241 unique locations. Each unique location was then classified using a modified NRPA park typology (Table 3.3). Certain responses could not be classified using the typology, as they were either too vague (e.g. “local park”) or referred to a large region that likely contained multiple types of green space (e.g. “the Adelaide Hills”). These responses were coded as ‘unknown’ or ‘general region’ respectively. The most frequently listed favorite places were ‘nature parks’ such as conservation reserves and National Parks (39.52%) as shown in Figure 3.1.

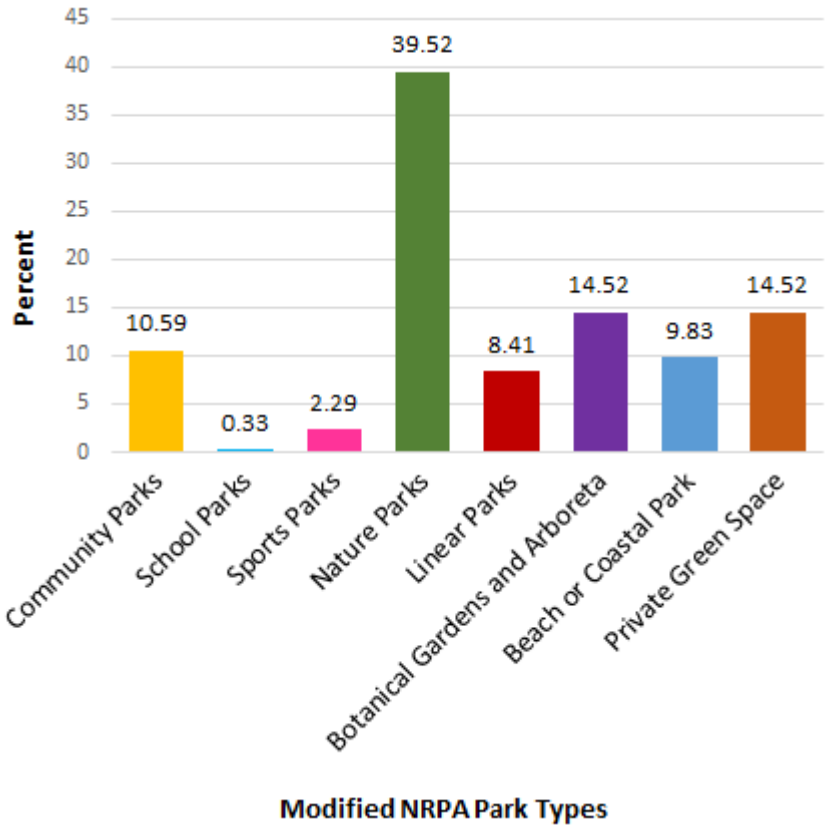


Figure 3.1. Popularity of different types of green space among participants' self-reported favorite places (*n* = 1022 favorite places).

The second most frequently listed favorite places were ‘private green spaces’ such as backyards (14.5%) and ‘botanical gardens and arboreta’ (14.5%). The apparent popularity of botanical gardens is particularly interesting, given the number of these green spaces in the State is considerably lower than any other type of green space, i.e. 14.5% of favorite places were comprised of 11 botanical gardens and arboreta, whereas ‘private green spaces’ (also 14.5%) were comprised of hundreds of different gardens and backyards. It should be noted that one of the radio segments promoting the study did discuss one of the State’s 11 botanic gardens, however, three botanic gardens featured in the 20 most popular parks in the State (Table 3.6.). The least popular types of favorite places were school parks (0.3%) and sports parks (2.3%).

Excluding private green spaces and ranked according to frequency of mention, the 20 most popular favorite places in South Australia are shown in Table 3.6. Again, the importance of nature parks is clear, with thirteen of the top 20 parks (65%) being comprised of natural areas such as conservation reserves and national parks. Although the frequency with which individual parks were mentioned might seem quite low, we must keep in mind that respondents were surveyed across a State that is almost one million square kilometers in size, contains 352 protected areas, and thousands of community parks. A total of 187 of the 241 places listed were only mentioned by one or two people. Results in Table 6 also suggest the importance of access to greenspace, with half of the parks listed being within close proximity to the majority of respondents (within 15 km of the Adelaide Central Business District). The noteworthy characteristic of the other half of parks, is they are very large and comprise diverse environments and multiple recreation opportunity classes.

Interestingly, despite 87% of South Australia being classed as arid (D.E.H, 2007), only two of the top 20 parks (Flinders Ranges National Park and Mount Remarkable National Park) are located in this arid region. Unlike most of the arid-land parks, both of these parks are situated in mountainous/hilly areas, as are many of the top 20 parks. Half of the top 20 parks (parks 4, 5, 7, 8, 10, 11, 12, 14, 17, and 18) are located in the Mount Lofty Ranges, which surround the capital city of Adelaide. Also of interest, despite a coastline of more than 3,700 km, only three parks listed in the top 20 were

coastal parks (parks 8, 9, and 13), although an additional five (parks 3, 11, 14, 15 and 16) included some form of blue space (river, lake or waterfall).

3.4.2. Loved attributes of natural favorite places

Respondents were asked the open-ended question, "What do you love about your favorite outdoor places?" Respondents were not prompted to refer to the physical attributes of the setting, nor their own experiences, benefits or memories, and were free to write whatever came to mind when thinking about their favorite places. Our first step was to identify the proportion of responses that referred to a specific attribute of the biophysical setting, a particular personal benefit, or an activity. Where multiple responses were provided, these were treated as separate statements. Statements that did not fit within a single node were coded into multiple nodes. This initial coding process resulted in 2,460 coded responses. The top 20 'loved' elements of respondents' favorite places are shown in Table 3.7. Fifteen of the top 20 elements were classified as 'setting attributes.' Overall, the most loved attributes of favorite places were birds and plants, which were mentioned with near equal frequency. For example: "The thing that makes it most special is the animal life in the area like native wild birds…" and, "I love watching the Australian native plants grow and attract bees and butterflies and birds…"

Table 3.6. The 20 most popular "favorite places" in the study, ranked by frequency of mention.

Rank	Park Name	Park Type	Frequency of Mention	Distance from CBD† (km)	Approximate park size (ha)
1	Adelaide Botanic Gardens	Botanical garden or arboretum	97	2.3	51
2	Flinders Ranges National Park	Nature park	57	466	93,400
3	Torrens River Linear Park	Linear park or trail	53	1.5	60*
4	Belair National Park	Nature park	45	12	835
5	Morialta Conservation Park	Nature park	33	12	533
6	The Adelaide Parklands	Community park	22	2	930
7	Mt Lofty Botanic Gardens	Botanical garden or arboretum	22	19	97
8	Deep Creek Conservation Park	Nature park	15	101	4,496
9	Innes National Park	Nature park	14	288	9,400
10	Cleland Conservation Park	Nature park	11	11	992
11	Onkaparinga River National Park	Nature park	10	33	1,500
12	Mt Lofty Summit	Nature park	10	18	With Cleland C.P.
13	Coorong National Park	Nature park	9	87	48,990
14	Waterfall Gully	Nature park	9	9.7	608
15	Thorndon Park	Community park	9	11	22
16	Murray River	Nature park	9	75	13,000
17	Wittunga Botanic Gardens	Botanical garden or arboretum	7	15	13
18	Kuitpo Forest	Nature park	6	42	3,600
19	Mt Remarkable National Park	Nature park	6	261	18,270
20	Hazelwood Park	Community park	5	6.4	15

† Travel distance from center of CBD

* Estimate: Linear park 30km in length; size calculation based on width of 20m.

Table 3.7. The top 20 “loved” elements of respondents' favorite outdoor places, ranked by frequency of mention.

Rank	‘Loved’ elements	Type	Frequency of Mention
1	Birds	Setting attribute	139
2	Plants, vegetation	Setting attribute	137
3	Aesthetics, beauty	Setting attribute	119
4	Wildlife, animals, fauna	Setting attribute	96
5	Walking	Activity	93
6	Nativeness (of species present)	Setting attribute	85
7	Solitude, privacy, escape crowds/city	Benefit	85
8	Quiet, peace, tranquility, silence	Setting attribute	81
9	Open space, space, vastness	Setting attribute	76
10	Accessibility and proximity	Setting attribute	71
11	Natural processes, seasonal changes	Setting attribute	63
12	Biodiversity and diversity	Setting attribute	54
13	Discovery, exploration, learning	Benefit	49
14	Fresh air, breeze	Setting attribute	45
15	Creeks, rivers, lakes, waterfalls	Setting attribute	45
16	Naturalness, wildness	Setting attribute	45
17	Rest and relaxation	Benefit	43
18	Beach, ocean, sea	Setting attribute	41
19	Family relations	Benefit	38
20	Sounds and smells of nature	Setting attribute	38

Aesthetics were also mentioned with a high degree of frequency, consistent with findings by Korpela and Hartig (1996), e.g. in explaining why they love their favorite place one respondent wrote: “It is an amazing place of great beauty on the edge of the desert… I greatly appreciate the natural beauty of this place…”.

Overall, 64.75% of statements referred to a setting attribute of the favorite place (e.g. “The remnant vegetation and the bird-life to be seen”); 20.7% referred to a personal benefit derived from the place (e.g. “It’s a fantastic place for renewing your spirit – escaping the city – and just relaxing”); and 14.5% of statements referred to an activity conducted in the favorite place, e.g. “…a wonderful gift to be able to visit for picnics or tennis or parties.”

Given our interest in providing usable information for park management and nature conservation in Australia, we then identified that 84.6% of loved ‘setting attributes’ referred to natural features of the environment, and 15.4% referred to human-made features such as toilets and walking trails. We further categorized the natural features into elements we believed park managers could modify (such as particular types of plants, e.g. “…I love seeing native plants (groundcovers, heaths, flowering creepers…)” and “…under the shade of beautiful trees, lots of simple things like old logs, mounds to climb on and play imaginative games. Hard to beat”) and those we considered were beyond reasonable human control (such as the presence of mountains, e.g. “…waterfalls, huge rock-faces and cliffs” and “…breathtaking sandhills and inlets and headlands that seem to never end”). Under this classification system, 70% of statements referring to a ‘setting attribute’ concerned a modifiable natural feature, 15.4% concerned a human-made feature, and 14.6% concerned an unmodifiable natural feature.

In regards to responses lending support to conservation objectives, references to terms such as ‘biodiversity’ and ‘native species’ were surprisingly frequent (e.g. “…great remnant biodiversity”, “It is a desert biodiversity hotspot”, “Tall trees attracting native birds…”, and “I love watching the Australian native plants grow”). Although explicit references to biodiversity were fairly common, there were also many comments about

the diversity of plant and animal species written in participants' own words, such as "…many trees of various varieties with different heights, colours and textures" and "…to see a koala now and then, the kangaroos we've seen on many days, but especially the birds! So many different kinds!" As a result, nativeness and biodiversity featured in the top 20 'loved' aspects of favorite places.

3.4.3. Relative importance of ART components in natural favorite places

To explore the relative importance of the four components of restorative environments in personal descriptions of favorite places, we re-coded responses to the question "What do you love about your favorite outdoor places?" We used a directed approach to content analysis, using words and phrases from previous restorative environments research, including the Perceived Restorativeness Scale (Hartig et al., 1997). In contrast to the inclusive and inductive method of content analysis we used when looking at the attributes of favorite places, this time we found that we were more likely to disagree on the category in which certain statements should be placed, particularly in the case of 'fascination'. We disagreed on approximately 5% of cases but after discussion we developed a shared understanding of how we would classify each component. Although we were able to reach a consensus (Table 3.5) we found that our results differed to those of previous research in this field (Korpela and Hartig, 1996, Korpela et al., 2001), in that fascination was found to be the most important component of favorite places, rather than the least important. This could however, simply be a function of focusing on favorite outdoor spaces, rather than favorite places in general. As shown in Figure 3.2, more than 50% of statements about what respondents' "loved" about their favorite places were categorized as being indicative of fascination. Extent was found to be the least important component, representing only 3% of responses. We considered 15.5% of responses to not fit within any of the ART categories, e.g. references to food or drink. When specific activities were given as the reason for loving a location, they were coded as "compatibility". We felt that references to an activity as being something respondents "loved" about their favorite places, were indicative of a match between their inclinations (to conduct that activity) and the suitability of the environment for

conducting it in. We coded any reference to a specific natural feature such as orchids, interesting rock formations, or animals as being a sign of fascination, i.e. these features have clearly captured the attention of the respondent, so much so that they have specifically remembered those features when calling their favorite places to mind. We believe such an action was justified, given the Kaplans' (1989, pp. 184-5) belief that when discussing 'fascinating' stimuli "it would also seem appropriate to include many of the objects found in nature" such as "sunsets and waterfalls, caves and fires". Similarly, Kaplan (1995, p. 172) suggests that "fascination can also come from content" such as "wild animals", and Berto et al. (2010, p. 494) also list "animals, people, water, nature" as fascinating objects. Such features may be sources of fascination because animate or moving objects (like animals and water) capture attention more effectively than static objects (Pratt et al., 2010). Although natural features have consistently been associated with the construct of fascination in previous research (e.g. Kaplan, 1995; Hartig et al., 1997; Joye et al., 2013), responses coded as 'fascination' in the present study did not necessarily refer to any attentional outcomes.

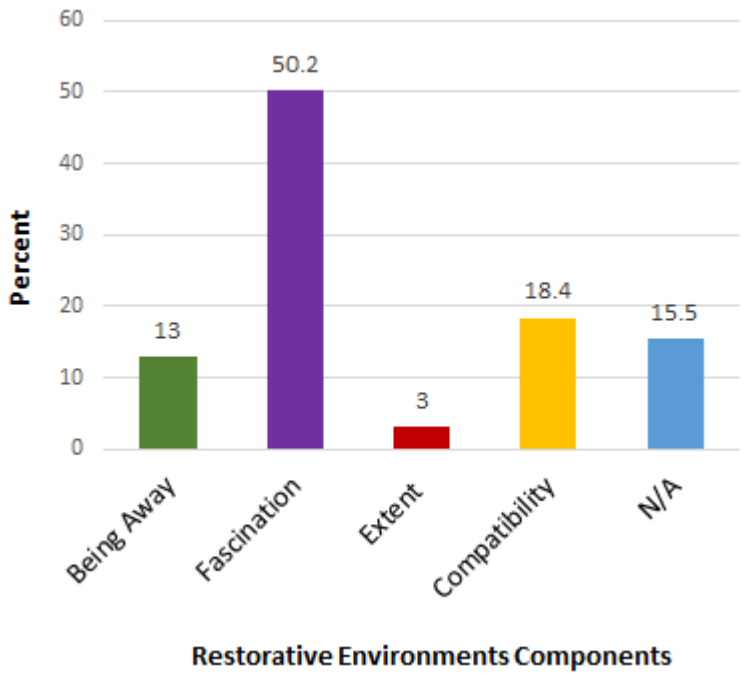


Figure 3.2. Relative importance of ART components after initial coding, when statements regarding natural features were coded as "fascination."

3.5. Discussion

3.5.1. Popular types of natural favorite places

The outdoor 'favorite places' of 447 South Australian respondents were classified into eight different green space types using a modified National Recreation and Parks Association (NRPA) park typology, similar to that used by Brown et al. (2014). When ranked according to frequency of mention, the types of natural places favored by respondents in our study follows much the same trend to that of Korpela et al.'s (2008) study in Finland. In both studies, the most popular types of favorite places are 'nature parks' (or 'extensively managed natural areas' such as woods and forests in the Finnish study). Nature parks accounted for nearly 40% of favorite places in the present study. The second most popular place type in the 2008 study was 'built-up green spaces' such as parks, which would be equivalent to 'community parks', 'botanical gardens', and 'linear parks', in the present study. Waterside environments such as beaches, followed by exercise areas and sports ovals, are ranked in the same order in both studies. 'Private green spaces' and 'school grounds' were not included in the Finnish study.

It is reasonable to speculate that people might derive greater restorative benefits from 'nature parks', due to the frequency with which they were identified as being favorite places in the present study, and in Korpela et al. (2008). In this same vein, we might expect to see the most popular 'favorite place type' align with the type of green space found to best facilitate psychological outcomes in studies explicitly examining the human benefits of different natural environments. To some degree there is such support, e.g. White et al. (2013) identified forests, coastal areas, and upland areas such as hills and mountains as being the most restorative environments of 16 different place types in England. South Australia is a relatively flat state, however, over 50% of the "top 20 favorite parks" were located in its hilly areas and by far the most frequently mentioned category was 'nature parks'. Furthermore, although South Australia is largely arid (D.E.H, 2007), most favorite places were located in the 13% of the state that is not arid, where rainfall is higher, and the presence of forested areas, creeks, and rivers is much

greater than in the rest of the state. Barton and Pretty (2010) found that exercising near a beach or river was associated with the greatest improvements in mood and self-esteem, but in Marselle et al. (2013) reductions in post-walk negative affect and perceived stress were associated with farmland and green corridors, but not coastal environments. In contrast to these studies, Marselle et al. (2015) found no significant difference between post-walk affect in different types of green spaces such as nature reserves, urban parks, and farmland. Determining whether these varying – and at times conflicting – results are due to methodological differences between studies, or simply reflect the many nuances of nature-health relationships, requires further research. It is possible that particular types of environments are more effective at facilitating specific psychological benefits, e.g. coastal environments might have a greater effect on restoration, mood, and self-esteem than other environments (Barton and Pretty, 2010, White et al., 2013), but not on negative affect or perceived stress (Marselle et al., 2013).

Marselle et al. (2015) found perceived restorativeness was significantly related to perceived naturalness and perceived biodiversity. Psychological benefits have been found to increase with perceived biodiversity in other studies (e.g. Fuller et al., 2007, Dallimer et al., 2012), however, species diversity is not always accurately detected by respondents. The extent to which participants are able to accurately perceive biodiversity is likely to differ, however, it is assumed that most people are able to distinguish between different types of natural settings, based on the method of self-reporting used to determine 'environment type' in many studies (Korpela et al., 2008, Korpela et al., 2010, Marselle et al., 2015, Marselle et al., 2013, White et al., 2013). Therefore, we can assume that people have some capacity to discern variations in natural attributes, and this has been the case in Fuller et al. (2007) and Johansson et al. (2014) with regard to plant diversity, and in Lamb and Purcell (1990) with regard to naturalness. Greater species diversity and naturalness may be more representative of certain park types in the present study. For example, 'nature parks' consisted largely of protected areas, which are known to harbor greater species richness and species abundance than unprotected natural areas (Gray et al., 2016). Furthermore, nature parks are more likely to exhibit the sensory cues (for example Dallimer et al. (2012) suggest that vegetation cover might be an important visual cue) that might influence people's perceptions of biodiversity, naturalness and in turn, restorativeness.

Identifying these sensory cues is of great importance to improving our collective understanding about how people perceive natural environments. At a time when many researchers are arguing that people are becoming increasingly disconnected from the natural world (e.g. Maller et al., 2008), it is valuable to know which aspects of nature people take notice of. It is of particular interest to explore whether people positively perceive features that contribute to the health of natural environments, as opposed to those that contribute only to human activities and experiences. Miller (2005, p. 431) asked, "if people no longer value nature or see it as relevant to their lives, will they be willing to invest in its protection?" Similarly, we might ask, if people no longer take notice of nature in their lives, will they ever come to value it? These questions are beyond the scope of the present study, however, working backwards, we were able to explore the aspects of nature that people use to explain their love for their favorite, and therefore most valued, natural environments.

3.5.2. Loved attributes of natural favorite places

Writing about one's experiences in nature has been espoused as a form of self-reflection that can improve one's connection with the natural world (Richardson et al., 2015). In the present study, participants were asked to list their favorite outdoor places, and to write about what they love about those places. Participants were not prompted to refer to the features of the environment, nor the benefits or experiences they derive from them. Thus, we believe the results go beyond determining aesthetic and recreation experience preferences, to exploring the transactional relationship between loved environments and the people who value them above all others. We consider that the relationship between person and environment can be mutualistic only if the environment also derives some benefit from being 'loved.' We can assume that a person is more likely to protect or advocate for a place that they value, however, it is still of interest to know what it is about valued environments that are important to the people who value them. Developing such an understanding is of particular importance to those designing campaigns aimed at improving nature attachment in disconnected individuals.

When exploring this issue, we first categorized the 'loved aspects' of favorite places as referring to a setting attribute, a benefit, or an activity. This process revealed that more than 60% of responses concerned a setting attribute, such as the presence of particular facilities or features of the environment. Of those setting attributes, approximately 85% referred to natural attributes, rather than artificial or human-created aspects of the environment. Some frequently mentioned attributes were to be expected, such as references to 'beauty', and the proximity of the favorite place to respondents' homes. The beauty of nature has long been considered an important component of human-nature relationships (e.g. Ulrich, 1983), and the proximity, or perceived proximity of parks to people's homes is often a predictor of park use (Giles-Corti et al., 2005, Wang et al., 2015). Interestingly, many responses referred to the micro-variables of natural settings, such as birds, plants, and wildlife. Birds and plants were mentioned with almost equal frequency and overall were the top two 'loved' attributes listed by respondents. The importance of plants was not surprising, as plants are almost synonymous with the idea of 'nature'. We believe the prominence of birds and wildlife in respondents' writing speaks to the value placed on ecological quality in loved environments. Although some animal species can thrive in low-quality environments, there were often specific references to 'native' and 'remnant' species, as well as the provision of 'habitat'. As suggested by Gobster et al. (2007), the ecological value of an environment might give pleasure to those individuals who are able to recognize it, and this appears to be the case for many of our respondents.

We did not expect many participants to explicitly cite 'biodiversity' as a loved feature of their favorite places, given previous research found 60% of respondents had never heard of the term 'biodiversity' (Lindemann-Matthies and Bose, 2008). However, a recent study suggests that ecological literacy in South Australia is quite high (Pitman and Daniels, 2016). Perhaps as a reflection of this relatively high level of environmental knowledge in the South Australian population, we discovered that biodiversity was actually frequently mentioned in responses. As a result, species diversity was one of the 20 most frequently mentioned attributes of favorite places. This might be due to the fact that more than 50% of respondents in the study held a bachelor's degree or higher, however, according to Pitman and Daniels (2016, p. 12) education and occupation are

not the only factors related to knowledge of the environment, and "ecological literacy need not be the exclusive domain of the highly educated or professionally employed."

Richardson et al. (2015) sought to identify the positive aspects of 'mundane' or 'everyday' nature that people took notice of during a five-day intervention designed to improve nature connectedness. Although respondents in the present study had an existing strong connection with nature, comparing the two studies reveals many similarities in the attributes found to be most important to respondents. The importance of micro-variables is reflected in both studies, with "specific aspects of nature" found to be one of the strongest themes arising from responses in Richardson et al. (2015, p. 613). Participants in both studies similarly identified 'beauty', 'wildlife', 'change', and 'sensations' as being important. 'Natural processes and seasonal changes' (in the present study) or 'growth and temporal changes' in Richardson et al. (2015), were found to be of great importance. Clearly, the ways in which loved environments change throughout the year is noticed by the people who value them, however, the fact that participants in Richardson et al. (2015) noticed change during only a five day period, we believe highlights an essential aspect of nature experiences in both 'mundane' and 'favorite' environments, which is that the living world is never static. Kaplan and Kaplan (1989) suggest that this 'ephemera' adds to the perception of fascination and may enhance feelings of 'being away'. Beyond this, it would appear that exposure to – and recognition of – dynamic, ever-changing environments can contribute to both the enhancement and maintenance of one's connection with nature. Although the lives of modern people are generally less dependent on the weather and the seasons than those of their ancestors', such variation is still an important and noticeable aspect of their nature experiences. Unlike the increasingly artificial and largely unchanging urban environments that many people now inhabit, the natural world undergoes constant transformation, which is clearly appreciated by many people. It is possible that management actions seeking to improve ecological quality in natural environments should be preceded by interventions that encourage park users to take notice of particular micro-variables and subtle natural processes. By initiating this early engagement, park agencies may find that their actions are received more favorably by a visitor base that has the ability and awareness to perceive the ways such actions simultaneously improve the environment and their enjoyment of it.

3.5.3. Relative importance of ART components in natural favorite places

According to Attention Restoration Theory (ART), all four components of restorative environments ('being away', 'fascination', 'extent', and 'compatibility') are essential to restorative experiences (Kaplan, 1995). Research in Finland and the United States found a significant difference in the apparent importance placed on compatibility and fascination in favorite places, with the latter component found to be of significantly less importance than the former (Korpela and Hartig, 1996, Korpela et al., 2001). As discussed previously, fascination is linked to concepts that may be indicative of ecosystem health, such as species diversity, naturalness, and wildness (Annerstedt et al., 2012, Winter, 2012, Van den Berg et al., 2014). It has been suggested that "experiencing a favorite place with reference to oneself and one's inclinations appears to be more important than inherently engaging or interesting properties of the environment per se" (Korpela et al., 2001, p. 585). Previous research suggests that actively noticing different aspects of natural environments, such as wildlife and changing foliage colors can improve one's connection with nature (Richardson et al., 2015), and in turn, nature connectedness is related to pro-environmental behaviors (Kals et al., 1999). Given the potential implications of this for conservation outcomes, we sought to explore whether personal descriptions of what people 'love' about their favorite places are indicative of a focus on 'self' (e.g. 'compatibility' between the environment and the activities and benefits desired), or indicative of a focus on the environment (e.g. 'fascination' with its interesting or beautiful features).

In the present study, statements associated with the idea of fascination featured prominently in the 'loved aspects' of favorite places, particularly those referring to micro-variables such as birds and plants. References to 'setting attributes' accounted for 65% of responses, which we believe could be suggestive of a difference between the relative importance of ART components in South Australian favorite places and those in Finland and the United States. The great value placed on fascination in our study may reflect the high level of ecological literacy in South Australia (Pitman and Daniels, 2016), as our survey respondents may be more likely to take notice of and appreciate

ecologically valuable, structurally-diverse, species-rich environments. This appreciation may indicate the existence of an 'ecological aesthetic' within the sample population (Gobster et al., 2007).

Care should be taken when comparing our results to those of previous research. One of the criticisms of restorative environments research is that most studies have been performed on undergraduate university students in Western Countries (Joye and van den Berg, 2013). Studies examining the restorative components of favorite places have similarly focused on students, e.g. the mean participant age across two of Korpela's studies was 23 years (Korpela and Hartig, 1996, Korpela et al., 2001), compared to a mean age in the present study of 52 years. It is possible that people's interest in taking notice of the world around them increases as they age, or conversely, that younger people are more interested in the 'self' than older people. It has been suggested that younger people, regardless of their generation, are more narcissistic than their elders (Roberts et al., 2010, Twenge et al., 2008). As "narcissism involves a wide range of self-regulation efforts aimed at enhancing the self" (Twenge et al., 2008, p. 877) and spending time in nature can be thought of as a form of "environmental self-regulation" (Korpela and Ylen, 2007, p. 139), it is possible that the contrasting results between our study and previous studies are age-related. Self-interest aside, it is also possible that the greater importance placed on 'compatibility' in previous research is more indicative of 'place dependence' rather than 'place identity', based on the traditional, two-dimensional model of place attachment (Williams et al., 1992). Although the two concepts are highly correlated, and both are concerned with a setting that is valued, 'place dependence' reflects a functional attachment based on the ability of the valued place to facilitate one's desired experiences, and 'place identity', reflects an emotional or affective bond. It has been suggested that functional attachment may initially draw people to an environment, and that repeated visits, over time, lead to an emotional attachment being formed, i.e. place dependence may precede place identity (Vaske and Kobrin, 2010). Given their mature age, perhaps more respondents in our study have had time to develop stronger emotional connections with their favorite place, and have come to place greater importance on the inherently interesting attributes of the place than on its ability to satisfy their needs.

In the present study, 'extent' was found to be the least important component of favorite place experiences. The reason for the apparent difference between our results and those of previous researchers (Korpela and Hartig, 1996, Korpela et al., 2001) may simply be due to the context. South Australians are accustomed to expansive lands and the opportunity to explore them in relatively uncrowded settings. For example, the State's capital city, Adelaide, is located less than 20 kilometers away from thousands of hectares of conservation land including Belair National Park; and the Central Business District itself is bordered by more than 900 hectares of interconnected parkland. It is possible that 'extent' is simply something people take for granted. Likewise, perhaps fascination is part of the national psyche. The Australian national anthem encourages people to take note of the fascinating aspects of the landscape, boasting, "Our land abounds in nature's gifts, of beauty rich and rare."

3.5.4. Limitations

Unlike previous research, the present study assumed that experiences of natural favorite places would be restorative, and did not directly measure restorative outcomes or perceived restorativeness. This is a limitation of the study, but we felt it was reasonable to assume most favorite places were indeed restorative environments based on previous research (Korpela et al., 2001). Attention Restoration Theory itself could also be considered a limitation. While we were interested in examining these relationships, we do concede that the limited sample of previous research may not justify the evolutionary and universalist assumptions underlying the theory (Joye and van den Berg, 2013). Lastly, this study is limited by the characteristics of its respondents, who were well-educated older people who clearly value nature. This is an interesting point of difference between our study and previous favorite places research, however, the results should be interpreted with caution. We acknowledge that our respondents' characteristics may be associated with the recruitment method used, as the radio station through which the study was promoted is more likely to attract older listeners. Place attachment researchers examining the effects of age, gender, and education on connections to place have not had consistent results (e.g. discussed in Rollero and De Piccoli, 2010), however, it is highly possible that the types of environments and natural attributes

identified as being most important will differ between socio-demographic groups. This study was largely explorative, and we believe further research is needed to improve our collective understanding of how different environmental attributes contribute to restorative outcomes.

3.6. Conclusion

Consistent with European research, the most frequently reported types of favorite places in the present study were ‘nature parks’ such as conservation areas and National Parks. Natural micro-variables such as birds and plants were the most frequently reported ‘loved’ attributes of favorite places, and in general respondents paid much more attention to the physical attributes of their favorite places, rather than their ability to facilitate personal benefits and activities. Accordingly, we found much greater importance was placed on ‘fascination’ in Australian favorite places than in previous research that identified fascination as the least important component of restorative experiences in favorite places. The possible reasons for this contrasting result include the focus on outdoor spaces, the comparably much higher mean age of our respondents, as well as their high level of education. Further, they were sampled from a population likely to have a reasonable knowledge of the natural environment and ecological processes. This is reflected in the personal importance respondents placed on the ecologically valuable attributes of their favorite places, such as the habitat they provide, as well as their species diversity and nativeness. We believe these findings can provide an anchor for marketing strategies aimed at increasing the public’s use of parks, and assist in the development of education programs aimed at improving people’s understanding of important but intangible concepts such as biodiversity. The findings of this study offer support for interventions that encourage people to take notice of and appreciate nature without overtly seeking to educate them. Beyond exploring *how* we can attract people to nature, we might also ask *why*, i.e. are the attributes of nature that are ‘lovable’ also those that provide health benefits? Further research exploring the ability of different types of environments and environmental features to facilitate psychological benefits, as well as the influence of environmental knowledge on individual perceptions of these environments is warranted. Understanding why people

love landscapes is crucial to global efforts to connect people with nature and ultimately improve population health, environmental stewardship and conservation outcomes.

Chapter 4. In Pursuit of Urban Sustainability: predicting public perceptions of park biodiversity using simple assessment tools

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4.1. Abstract

In the face of ongoing global species loss, the pursuit of sustainable social-ecological systems necessitates that urban societies see the value in biodiversity, now more than ever before. Yet practical strategies to enhance society's appreciation of biodiversity are limited by the disparity that exists between perceptions and expert assessments of biodiversity. To enhance our understanding of why this disparity exists, a series of non-expert-dependent assessment tools were used to examine the ecological attributes of 134 urban parks. The ability of these tools to predict perceived biodiversity was explored using ordinal regression modelling of 1,894 perception responses from 840 individuals. Despite previous researchers theorising otherwise, changes in vegetation structural heterogeneity were too subtle to significantly influence perceptions. Vegetation cover, habitat diversity, and a proposed Urban Park Naturalness Index (UPNI) were the strongest predictors of perceived biodiversity, explaining 31% of respondent's perceptions. Bird species richness significantly influenced perceptions of naturalness but not biodiversity. Despite a relatively weak fit between perceptions and objective measures, we demonstrate how subtle changes in assessed attributes significantly affect predicted biodiversity perceptions. For example, every additional habitat type within a park increases the odds of it being in a higher perceived biodiversity category by 32%. We propose further development of simple assessment tools such as the UPNI that provide valuable insights into the visual cues that influence perceptions of biodiversity and as such can aid the sustainable design and management of urban green spaces.

Keywords

Biodiversity; species richness; perceptions; green space; naturalness; urban parks.

4.2. Introduction

Human health is inexorably linked to the health of the natural world (Lang and Rayner, 2012). Our planet's unique ecosystems provide countless services that make our existence possible, from supplying food, fuel and medication, to purifying the air we breathe and the water we drink. Even with considerable technological advancement, it is likely that many ecosystem services would be impossible for humanity to replicate or substitute (Chivian and Bernstein, 2010). Biodiversity is an important component of ecosystem health (Costanza and Mageau, 1999), contributing to an ecosystem's ability to maintain its structure and vigour, and to be resilient to stress over time (e.g. Tilman et al., 2014, Tilman, 1996, Peterson et al., 1998). A reduction in biodiversity is known to limit the ability of ecosystems to perform certain services that directly benefit human health, such as suppressing the spread of infectious diseases like hantavirus and Lyme disease (Keesing et al., 2010). Additionally, self-reported well-being benefits have been associated with natural environments that are perceived as having greater species richness, however, there is thought to be a significant mismatch between laypeople's perceptions of biodiversity and objective, expert assessments (Dallimer et al., 2012).

Despite our unquestionable dependence on biodiversity, every day human actions alter ecosystems and threaten biological diversity. Many people have little awareness, let alone understanding, of the ecological processes that sustain their lives (e.g. Miller, 2005, Lindemann-Matthies and Bose, 2008), and in large part this growing disconnection between humans and nature is a result of urbanisation. In many urban societies, parks and private gardens are the most frequently experienced forms of nature, and it is likely that for some individuals, urban green spaces will be the only natural environments directly experienced throughout most of their lifetime. Clearly, urban green spaces must play a pivotal role in improving the public's connection with nature and improving their understanding of important ecological concepts. To succeed at this, we must not only ensure that urban parks exhibit the principles and processes we seek to conserve, such as biodiversity, but that park users are able to perceive these concepts with some degree of accuracy. Engaging people in a dialogue about the importance of biodiversity has limited value if we don't fully understand how people perceive

biodiversity. To that end, this paper proposes a simple, non-specialist-dependent park assessment tool that examines the visual cues that influence the public's perceptions of biodiversity, and seeks to develop an understanding of how closely those perceptions reflect scientific measures of that same concept.

4.2.1. Public understanding of biodiversity

Research suggests that laypeople often have little ability to perceive biodiversity accurately (e.g. Dallimer et al., 2012, Lindemann-Matthies and Bose, 2008). The relatively poor understanding of biodiversity shared by much of the public is highlighted by Lindemann-Matthies and Bose (2008) who found that 60% of respondents had never heard of 'biodiversity', and Balmford (2002) who discovered that British children were able to identify more synthetic Pokemon 'species' than species of local wildlife. In a French study, Shwartz et al. (2014) found despite reporting strong preferences for a rich diversity of species, visitors did not notice species diversity in the parks they visited. Dallimer et al. (2012) examined relationships between self-reported psychological benefits and bird, butterfly and plant species richness, and concluded that all three were inaccurately detected by respondents. The problem is exacerbated by the fact that highly used urban parks are often poor reflections of healthy ecosystems, due to their high degree of disturbance (Zipperer and Guntenspergen, 2009), lack of native biological diversity (Ignatieva and Stewart, 2009), and their dependence on human inputs (Parés-Franzi et al., 2006). This raises concerns about the natural environments that come to be most familiar to urban societies, particularly when first-hand experiences of nature are thought to be the key mechanism through which people learn about the environment and the issues it faces (Miles, 1991).

4.2.2. Measuring biodiversity and naturalness

Congruence between the public's perceptions of environmental quality and the assessments of experts is vital to efforts to improve urban sustainability (Bonnes et al., 2007). When considering biodiversity in relation to human perceptions, measures that

look at obvious environmental variations such as habitat heterogeneity or vegetation cover, may be more appropriate than those that use very fine, small scale measures such as counts of species richness and abundance, where differences may be too subtle for the untrained eye to comprehend (Bonnes et al., 2007). However, measures that are too broad may have no measurable effect on humans, and offer little basis on which to improve urban biodiversity. Jorgensen and Gobster (2010, p. 356) lend support to Fuller et al.'s (2007) hypothesis that "structural heterogeneity may be the principal means by which humans detect biodiversity in the landscape around them". Many studies have found associations between structural heterogeneity (e.g. variation in plant heights) and biodiversity, with greater heterogeneity generally supporting greater species richness (for a review see Stein et al., 2014). Lamb and Purcell (1990) found structural heterogeneity influenced people's perceptions of naturalness in Australian landscapes. It is possible that the public are more likely to understand the concept of naturalness, as it has various applications in everyday life, e.g. fabrics, foods, and remedies touted as being "natural" are familiar to most Western people (Ridder, 2007). Conversely, references to "biodiversity" are unlikely to be encountered outside of discussions of conservation biology, which may be one reason why the public has a poor understanding of the concept (Lindemann-Matthies and Bose, 2008, DEFRA, 2011). As Aplet and Cole (2010, p. 14) suggest, "any word worth using must have meaning to both the user and the audience. Clearly, by its frequent use, *naturalness*… meets that test." Thus, the development of tools to assess perceptions of biodiversity should also assess more readily understood attributes, such as naturalness. In this study, we have used assessments of structural heterogeneity as a proxy for "biodiversity", and have defined "naturalness" as being the proportion of natural versus anthropic elements in urban parks, as well as a park's level of dependence on human input and extraction.

A potential confounder that must be considered in examining this relationship is that of park size. There is an established body of research highlighting the importance of park size to biodiversity, i.e. the species-area relationship (Arrhenius, 1921), an ecological principle that holds true even in urban parks (Nielsen et al., 2014). However, little research has examined the relationship between park size and human perceptions of biodiversity. One reason may be the difficulty people experience in estimating size accurately. In Europe, Nordh et al. (2009) found that perceptions of park size amongst

respondents (n=10) were highly correlated with one another, but only moderately correlated with objectively measured park size. Qiu and Nielson (2015) found most respondents perceived one park as being larger than another twice its size, suggesting topographical variation and a park's visual seclusion may influence perceptions of size.

Given the resource-intensiveness of conducting in-situ environmental assessments, and the dependency conservation agencies have on volunteers who might not necessarily be expert in specific aspects of biological inventory (O'Brien et al., 2008), a focus on quick and easy-to-use tools that are accessible to laypeople is warranted (such as in Tzoulas and James, 2010). Methods that are simple and efficient allow for a greater number of green spaces to be assessed than has occurred previously, e.g. three sites were assessed in Tzoulas and James (2010); 15 sites in Fuller et al. (2007); and 34 sites in Dallimer et al. (2012). Machado (2004, p. 100) argues there is a growing demand for tools that allow for the rapid assessment of environments, and that pragmatic trade-offs between optimal scientific rigour and considerations of time and economic resources are necessary. Machado (2004) champions the idea of indices as potential tools, and such indices have been implemented in this study.

4.2.3. Research focus

This study sought to develop a non-expert-dependent park assessment tool for biodiversity that incorporated the sensory cues that might influence public perceptions of biodiversity. To this end, urban parks were assessed using a series of checklists developed following a review of existing tools that examine structural heterogeneity, habitat heterogeneity, and anthropic elements, and the results were compared with those of a proposed 'Urban Park Naturalness Index' (UPNI) adapted from Machado (2004). Results were also compared with park size and estimates of vegetation cover generated remotely using i-Tree Canopy software. Lastly, we conducted comparisons between each of these measures and self-reported perceptions of biodiversity and naturalness. In doing so, we sought to (a) explore the visual cues that most strongly influence public perceptions of biodiversity and naturalness, and (b) determine whether estimates of

ecological quality generated using rapid assessment tools reflect public perceptions of biodiversity in Australian urban parks, using a significantly larger sample of green spaces than in Fuller et al.'s (2007) and Dallimer et al.'s (2012) landmark studies.

4.3. Methods

4.3.1. Study site

The study took place across three metropolitan Local Government Areas (LGAs) in the state of South Australia. The cities of Burnside, Unley, and Mitcham are located towards the south-eastern corner of the state's capital city, Adelaide. Combined, they include 150,000 residents and cover an area of 118 km^2 (Australian Bureau of Statistics, 2017d). Both the City of Mitcham and the City of Burnside contain a high number of green spaces, whereas the more densely populated City of Unley contains far fewer urban parks per capita, e.g. 0.8ha of open space per 1000 residents in Unley, compared with 7.2ha of open space per 1000 residents in Burnside (LGASA, 2014).

4.3.2. Park selection

A database of every public green space within the study area was created using GIS data obtained from each of the three LGAs. In selecting parks to include in the study, we were cognizant that each park would undergo a time-consuming on-site assessment, as they would be assessed using multiple tools by a single assessor. Thus, maximum park size was limited to 8ha (approximately 20 acres) for on-site assessments, which was considered to be a feasible area for a single person to assess. Twenty-seven parks larger than 8ha exist in the study area, and following consultation with LGA representatives, 13 of these were assessed remotely using i-Tree Canopy and included in the public questionnaire as they were known to be popular parks and managers believed they were particularly relevant to biodiversity conservation. To ensure adequate sampling, the minimum park size was limited to 0.4ha (approximately 1 acre) based on the assumption

that small parks were likely to attract fewer visitors than large urban parks. Although Tzoulas and James (2010) set their minimum park size to 1ha, we were curious to explore whether public perceptions of biodiversity and naturalness could still be high in pocket parks, considering planners will find it increasingly difficult to establish large parks as housing densities and property prices rise. In total, 134 parks were included in the study; 121 of which met the 0.4-8ha size requirement and underwent on-site assessments.

4.3.3. On-site assessments

The assessment tools comprised three park element checklists, and a modified Naturalness Index (Machado, 2004). The checklists examined 'structural elements', 'habitat types' and 'anthropic elements' (i.e. infrastructure and recreational facilities). They were developed in consultation with relevant experts and tested for consistency among multiple assessors in 12 urban parks and demonstrated high internal consistency ($\alpha = 0.96$). The final assessments were all done by one of the initial assessors. See Appendix L for assessment procedure.

4.3.3.1. Urban Park Naturalness Index

The UPNI (Table 4.1) was modified from Machado's (2004) Index of Naturalness, which evaluates a system's naturalness on an 11-point scale from [0] '100% cultural or artificial' to [10] '100% natural'. Across 10 different categories, the index considers the natural and anthropic elements present in the landscape, and the extent to which energy and matter are input and/or extracted from the system. The original index was designed to be "intuitive even for the general public" (Machado, 2004, p. 100). However, our initial testing revealed confusion among assessors, both lay and science-trained, due to the repetition and ambiguity of many descriptions in the index, and the assessments differed quite markedly at times among assessors. Hence to improve consistency, the index was modified to include specific descriptions and examples relevant to Australian

urban settings. The new tool simplified the assessment process, by using a five-point scale with no repetition of descriptions between scale points, and a reduced set of items relevant to urban parks (e.g. ‘fragmentation’ from the original index was removed as it is less applicable in urban settings, which are invariably fragmented). Modifications were made in consultation with ecologists to ensure rigour and with consideration to what a non-specialist could reliably assess. Each item is given a score from [1] ‘100% anthropic’ to [5] ‘100% natural’. Percentages and/or specific examples were given to guide assessors; except in cases where the difference between scale items was sufficiently clear. A mean Naturalness Score is calculated by summing scores for each element and dividing by the number of items in the UPNI (typically 9 but 8 in cases where the park did not contain any water bodies).

Table 4.1. The Urban Park Naturalness Index (UPNI) adapted from Machado's (2004) Index of Naturalness.

INDEX			← ANTHROPIC				NATURAL →
			1	2	3	4	5
Biotic Elements	**Nativeness**	**Ground layer vegetation (<1m high)**	Exclusively/almost exclusively exotic species	Predominantly exotic species	Mixed native and exotic species	Predominantly native species	Exclusively/almost exclusively native species
		Tree and shrub vegetation (>1m high)	Exclusively/almost exclusively exotic species	Predominantly exotic species	Mixed native and exotic species	Predominantly native species	Exclusively/almost exclusively native species
		Bird species	Exclusively/almost exclusively exotic species	Predominantly exotic species	Mixed native and exotic species	Predominantly native species	Exclusively/almost exclusively native species
Artificial Elements	**Artefacts**	**Percentage of park impermeable***	81-100% impermeable surfaces	61-80% impermeable surfaces	41-60% impermeable surfaces	21-40% impermeable surfaces	0-20% impermeable surfaces
	Pollutants	**Physical pollutants**	Frequent presence of litter/pollutants *and* presence of chemical contaminants, e.g. oil spills	Frequent presence of litter/pollutants throughout park	Occasional presence of litter/pollutants throughout park	Presence of litter/pollutants rare, isolated	No evidence of litter/pollutants
Input and Extraction	**Irrigation**	**Percentage of park irrigated**	81-100% irrigated	61-80% irrigated	41-60% irrigated	21-40% irrigated	0-20% irrigated
	Mowing	**Percentage of park mown**	81-100% mown	61-80% mown	41-60% mown	21-40% mown	0-20% mown
Dynamics	**Water****	**Naturalness of water bodies**	Closed/artificial, e.g. swimming pool	Constructed by humans, important inputs (e.g. reservoir)	Free flowing, some structural modification *and* human inputs (e.g. external water piped into)	Free flowing, some structural modification, e.g. concrete reinforced banks	Natural, free flowing, no human inputs
	General	**Level of human dependence**	Full external dependence, forced, unconnected	Forced by humans, important dependence	Oriented, some dependence, but mostly self-sustained	Natural, minimal external dependence (e.g. bins)	Natural, no external dependence

* Include paving, concrete, rubber, and the footprint of any buildings

** Only include water bodies. Do not include irrigation. If no water body present, exclude item.

4.3.3.2. Structural elements and habitat type checklists

The checklists of structural elements (Appendix C) and habitat types (Appendix D) were created after reviewing existing assessment tools designed to estimate ecological quality, monitor environmental change, or classify land use types across large areas (i.e. Tzoulas and James, 2010, Machado, 2004, Young and Jarvis, 2001a, Whitford et al., 2001, Hermy and Cornelis, 2000, Fuller et al., 2007, Honnay et al., 2003, Livingston et al., 2003, Freeman, 1999, Pauleit and Duhme, 2000, Freeman and Buck, 2003). The structural elements checklist provided a simple count of different natural features within each park, such as plants of different heights and life-stages; non-plant elements representing potential micro habitats such as large rocks; and topographical features such as hills and cliff faces. The structural elements checklist, comprising 31 items, was designed to give an indication of the vertical distribution of ecosystem components within a park, and did not examine the total area covered by each element, or the ways in which they were spaced apart or grouped together, i.e. their horizontal distribution. As a result, the structural elements checklist gives no indication of whether a particular natural feature on the checklist is represented by a single individual (e.g. one tree) or it dominates the park (e.g. a plantation). For this reason, a checklist of habitat types, comprising 20 items, was also used. This was guided by the 'planar elements' components used by Hermy and Cornelis (2000), and the Australian vegetation and landform habitats identified by Simpson and Day (2004). In the habitat types checklist, ecosystem components are only selected if they occupy an area of at least 100m^2.

4.3.3.3. Anthropic elements checklist

The checklist of anthropic elements, consisting of 33 items, was adapted from existing assessment tools (Appendix E) as well as our own initial on-site observations. It examines the quality of urban parks from a human use perspective, i.e. their suitability for a range of human activities, as well as their accessibility, safety, and cleanliness. The development of the checklist was guided by tools such as the Quality of Public Open Space Tool (POST) (Broomhall et al., 1996) and the Community Park Audit Tool (CPAT), as well as our own initial on-site observations. Like the other checklists, this

checklist was designed to allow non-specialist users to make quick assessments regarding the variety of anthropic elements within each park. The checklist includes attributes related to active recreation (e.g. tennis courts), passive recreation (e.g. picnic tables), and human-constructed aesthetic elements (e.g. statues, artwork). Existing tools explore some of these attributes in great depth, however, they rely on assessors' judgements to rate the condition or quality of particular elements, and are much more time consuming. The chief concern in this study was the absence/presence and variety of park elements, rather than their condition.

4.3.4. Vegetation cover assessment

A total of 44 parks were assessed for vegetation cover. The inclusion criterion was that parks had to have been identified by at least 10 respondents, to allow comparisons with respondent perceptions. Each park was remotely classified using i-Tree Canopy software. This peer-reviewed software was developed by the USDA Forest Service and allows the user to quickly and systematically assess aerial photographs using Google Earth™ imagery. The software randomly places points throughout a specified area and the assessor visually determines which pre-defined landscape feature the point has landed on. For example, Jacobs et al. (2014) used four landscape feature categories in their assessments of canopy cover in Australian LGAs: hard surface; tree; shrub; and grass or bare ground. In the City of Oxford, United Kingdom, Rogers and Jaluzot (2015) used i-Tree Canopy to classify the city into eight broad land classes, such as agricultural land, nature reserves, and transport areas. They classified trees and shrubs as 'tree cover' regardless of the land class they were situated within. Although Jacobs et al. (2014) saw fit to separate trees and shrubs in their i-Tree Canopy assessments, Rogers and Jaluzot (2015, p. 4) argue, "it is difficult or impossible to differentiate between trees and shrubs using aerial photography." Following testing, the authors of the present study agreed with this view and included trees and shrubs under the same landscape feature class. The five landscape feature classes used were: vegetation cover; impermeable surfaces; grass/bare ground; water bodies; and 'other' (e.g. cars). Consistent with the sampling rates used by Rogers and Jaluzot (2015), a minimum of

500 random points were sampled until the standard error for all land feature classes was less than 2%, irrespective of park size.

4.3.5. Perceptions of green space

To evaluate human perceptions of natural environments, a public questionnaire was distributed to 4000 households across the three LGAs during summer. Each LGA was divided into zones. Within each zone, specific quotas of surveys were allocated to major and minor roads, and delivered to every third letterbox along these roads. Questionnaires were delivered with a reply-paid envelope, and a colour-printed A3 map of the study area, highlighting the 134 parks included in the study (Appendix A). Respondents were asked to select up to four green spaces they were familiar with, and to rate on a seven-point scale the variety of plant and animal species present, the degree of naturalness, and the amount of natural shade cover from vegetation at each of those parks. A suite of demographic questions, the Nature Relatedness Scale (Nisbet et al., 2009), and questions on use patterns and biodiversity knowledge were also included.

4.3.6. Data analysis

We first examined correlations between park size and six different park attributes, estimated using our assessment tools. We then examined correlations between public perceptions of biodiversity and naturalness, and park attributes. We used ordinal regression to separately model the relationship between the rapid assessment tools and respondents' perceptions. Model selection was accomplished using a combination of traditional exploratory modelling techniques, including stepwise regression and subset regression approaches, to identify key variables in the model. A number of ordinal regression models were then applied, with each model compared using the AIC (Akaike Information Criterion), BIC (Bayesian Information Criterion), and pseudo R-squared values. Variance Inflation Factors (VIFs) were also used to detect issues of multicollinearity. To identify the strongest predictor, or combination of predictors, each

variable was standardized and used to construct the final regression model. The best predictors were then identified as the rapid assessment tools with the largest parameters in the model. From this, we were able to determine which of our rapid assessment tools had the strongest linear association with respondents' perceptions of two key indicators of ecological quality, i.e. biodiversity and naturalness. Analyses were conducted in SPSS version 24, and R version 3.4.0.

4.3.7. Respondent characteristics

A total of 840 questionnaires were returned, giving a final response rate of 21%. Unseasonal rainy weather during the delivery period, which resulted in an indeterminate number of water-damaged questionnaires and potentially a reduced interest in the outdoors may have contributed to the response rate. Given budget constraints and the method of questionnaire distribution, reminder letters were not distributed. Overall, respondents were fairly evenly spread throughout the three LGAs, with 31% from Unley, 32% from Mitcham, and 37% from Burnside. Respondents were largely female (62%); highly educated (64% with a bachelor degree or higher); married or in a de facto relationship (74%); and either working full-time (36%) or retired (34%). Although the greatest percentage of respondent households were couples with no children at home (37%), there were also many sole adult households (18%), families with children over 18 years (17%), and families with children aged 7-18 years (17%). Respondent ages ranged from 15 to 99 years, with a median age of 59 years. Comparing this to national census data showed that despite the large sample size, our respondents were not strictly representative of the populations in the three LGAs, which are younger (median age of 42 years) with a lower proportion of females (52.5% female) (Australian Bureau of Statistics, 2017a, 2017b, 2017c).

4.4. Results

4.4.1. The relationship between park attributes and park size (area in ha)

On-site assessments of park attributes (bird species richness, naturalness, structural heterogeneity, habitat heterogeneity and anthropic element diversity) were conducted in 121 urban parks between 0.4ha and 8ha in size. Pearson's correlations were run to determine the relationship between park size and each of the park attributes. As shown in Table 4.2, correlations between park size and park attributes ranged from very weak (park size and naturalness: $r = 0.10$) to moderate (e.g. park size and habitat heterogeneity: $r = 0.52$).

4.4.1.1. Vegetation cover

Vegetation cover was estimated using i-Tree Canopy software for 24 parks selected by 10 or more questionnaire respondents. This included 13 parks larger than 8ha that were not assessed on-site. Vegetation cover ranged from 12.2% to 74.2%. A Pearson's correlation was run to determine the relationship between vegetation cover and park size. There was a moderate, positive correlation between the percentage of the park covered by tree or shrub vegetation and the size of the park ($r = 0.49$, n = 24, $p < 0.001$).

Table 4.2. Correlations between assessed park characteristics and park size

Dependent variable	Independent variable	Range	Result	Significance	*n*	Strength
Bird species richness	Park size	0-13	$r = 0.46$	$p < 0.05$	121	Moderate
Naturalness	Park size	35%-93%	$r = 0.10$	$p < 0.05$	121	Very weak
Structural heterogeneity	Park size	9-30	$r = 0.30$	$p < 0.05$	121	Weak
Habitat heterogeneity	Park size	2-10	$r = 0.52$	$p < 0.05$	121	Moderate
Anthropic element diversity	Park size	0-16	$r = 0.43$	$p < 0.05$	121	Moderate
Vegetation cover	Park size	12.2%-74.2%	$r = 0.49$	$p < 0.05$	24	Moderate

4.4.2. Associations between park attributes and public perceptions of biodiversity and naturalness

In order to determine the strength with which different assessment tools reflected respondents' perceptions of biodiversity and naturalness, we examined polyserial correlations to reflect the ordinal nature of the perception ratings. As shown in Table 4.3, correlations with perceived biodiversity ranged from very weak (e.g. anthropic element diversity $r = -0.10$), to moderate (vegetation cover $r = 0.53$ and naturalness $r = 0.44$). Similarly, correlations with perceived naturalness ranged from very weak (e.g. bird species richness $r = 0.16$) to moderate (vegetation cover $r = 0.56$ and naturalness $r = 0.45$). Both perceived biodiversity and perceived naturalness are most strongly correlated with vegetation cover and park naturalness.

Table 4.3. Polyserial correlations between assessed park characteristics and perceptions of biodiversity and naturalness

Dependent variable	Independent variable	Result	Significance	*n*	Strength
Perceived biodiversity	Bird species richness	$r = 0.229$	$p < 0.001$	1894	Weak
Perceived naturalness	Bird species richness	$r = 0.157$	$p < 0.001$	1889	Very weak
Perceived biodiversity	Naturalness	$r = 0.437$	$p < 0.001$	1894	Moderate
Perceived naturalness	Naturalness	$r = 0.448$	$p < 0.001$	1889	Moderate
Perceived biodiversity	Structural heterogeneity	$r = 0.385$	$p < 0.001$	1894	Weak
Perceived naturalness	Structural heterogeneity	$r = 0.285$	$p < 0.001$	1889	Weak
Perceived biodiversity	Habitat heterogeneity	$r = 0.306$	$p < 0.001$	1894	Weak
Perceived naturalness	Habitat heterogeneity	$r = 0.184$	$p < 0.001$	1889	Very weak
Perceived biodiversity	Anthropic element diversity	$r = -0.093$	$p < 0.001$	1894	Very weak
Perceived naturalness	Anthropic element diversity	$r = -0.212$	$p < 0.001$	1889	Weak
Perceived biodiversity	Vegetation cover	$r = 0.528$	$p < 0.001$	1942	Moderate
Perceived naturalness	Vegetation cover	$r = 0.562$	$p < 0.001$	1943	Moderate
Perceived biodiversity	Park size	$r = 0.378$	$p < 0.001$	2992	Weak
Perceived naturalness	Park size	$r = 0.319$	$p < 0.001$	2985	Weak

4.4.3. Predicting public perceptions of biodiversity

Ordinal regression was used to determine which assessment tools best predicted respondents' perceptions of biodiversity, with the model trained using 70% of the data and tested using the remaining 30% of the data. Before creating the model, we tested for multicollinearity between the six tools by examining Variance Inflation Factor scores

(VIFs). According to Bowerman and O'Connell (1990) all VIFs in the model should be less than 10. Several variables in our study – structural heterogeneity, anthropic element diversity, and vegetation cover – exhibited high VIFs, indicating that these variables had severe multicollinearity issues and that one or more of them should be excluded from the model. To determine which variable(s) should be eliminated, we employed traditional exploratory modelling techniques, including subset regression. A series of ordinal regression models were fitted, with each model excluding just one of the three variables. The resulting models were compared using the AIC, BIC, and Nagelkerke R-squared values. The model that eliminated anthropic elements could be improved by also excluding structural heterogeneity and bird species richness, which were not significant contributors to the model. Thus, the final model was comprised of three of the rapid assessment tools, as shown in Table 4.4. All VIFs were less than 4.

The final model had the lowest BIC (2368.2) with an AIC of 2327.4 and Nagelkerke R-squared of 0.307. This suggests that the model may be explaining approximately 30.7% of the variability in perceived biodiversity, indicating that there are variables beyond the considered assessment tools which impact on perceptions of biodiversity. When applied to testing 30% of the data, the model had an agreement of 23.5% and a kappa of 0.1862 indicating the model has poor predictive performance. However the parameters in the model do provide insight into the relationship between the park attributes and biodiversity perceptions.

Table 4.4. Parameter estimates for the ordinal regression model for perceived biodiversity and the corresponding 95% confidence intervals (CI). Each of the variables is a significant predictor in the model ($p < 0.05$).

Variables	**Estimate (95% CI)**	**Standard Error**	**p-value**
Naturalness Score	0.042 (0.021, 0.063)	0.011	< 0.001
Habitat Types	0.275 (0.136, 0.414)	0.071	< 0.001
Vegetation cover	0.029 (0.016, 0.042)	0.007	< 0.001

The exponential of these parameter estimates was then used to show how the odds of being in a higher "perceived biodiversity" category (on a 7-point scale) changes when each of the assessment scores increases by one. For example, if the assessed "naturalness" of a park were to increase by 1% on the UPNI, the odds of being in a higher "perceived biodiversity" category increases by 4.3%. Interestingly, for every additional habitat type, the odds of being in a higher perceived biodiversity category increase by 31.7%.

By standardising the predictor variables we were then able to make direct comparisons between each of the coefficients in the model. Table 4.5 shows that vegetation cover and naturalness score are the strongest predictors of perceived biodiversity amongst the considered assessment tools.

Table 4.5. Parameter estimates from the final ordinal regression model for perceived biodiversity with standardized variables to determine the strongest predictor.

Variable	Standardized estimate (95% CI)	Standard Error	t Value
Naturalness Score	0.522 (0.265, 0.782)	0.132	3.966
Habitat Types	0.293 (0.145, 0.441)	0.076	3.872
Vegetation cover	0.558 (0.310, 0.807)	0.127	4.407

4.4.4. Predicting public perceptions of naturalness

Ordinal regression was used to determine which assessment tools best predicted respondents' perceptions of naturalness. Once again, structural heterogeneity, anthropic element diversity and vegetation cover exhibited high VIFs. As with perceived biodiversity, we fit a series of ordinal regression models whereby each model excluded

just one of the three variables, and compared their AIC, BIC, and Nagelkerke R-squared values. This time, the model that eliminated anthropic elements was improved by also excluding habitat types, which was not a significant contributor to the model. The final model for perceived naturalness was comprised of three assessment tools, as shown in Table 4.6. All VIFs were less than 4.

The final model had the lowest AIC (2318.8) and highest Nagelkerke R-squared (0.293) of all models tested. All models had comparable BIC scores. The Nagelkerke R-squared suggests the model may be explaining 29.3% of perceived naturalness. When applied to the testing data, the model for perceived naturalness had an agreement of 27.6% and a kappa of 0.2440, indicating poor predictive performance, which may be improved by the inclusion of variables beyond the assessment tools considered thus far. However, the model can be used to gain insight into the relationship between these assessment tools and perceptions of naturalness.

Table 4.6. Parameter estimates for the ordinal regression model for perceived naturalness and the corresponding 95% confidence intervals (CI). Each of the variables is a significant predictor in the model ($p < 0.05$).

Variable	Estimate (95% CI)	Standard Error	p-value
Naturalness Score	0.052 (0.031, 0.073)	0.011	< 0.001
Bird Species Richness	0.079 (0.000, 0.159)	0.041	0.0507
Vegetation cover	0.028 (0.015, 0.041)	0.007	< 0.001

The exponential of the parameter estimates provide a measure of the change in the odds of being in a higher "perceived naturalness" category when each of the assessment scores increases by one unit. If the assessed "naturalness" of a park were to increase by 1% on the UPNI, the odds of being in a higher "perceived naturalness" category would increase by an estimated 5.3%. Every additional bird species increases the odds of having higher perceived naturalness by 8.2%. All predictor variables were standardised to allow for direct comparisons between the coefficients in the model. Table 4.7 shows

that the UPNI is the strongest predictor of perceived naturalness amongst the assessment tools considered.

Table 4.7. Parameter estimates from the final ordinal regression model for perceived naturalness with standardized variables to determine the strongest predictor.

Variable	Standardized estimate (95% CI)	Standard Error	t Value
Naturalness Score	0.654 (0.392, 0.918)	0.134	4.871
Bird Species Richness	0.139 (0.000, 0.279)	0.071	1.952
Vegetation cover	0.528 (0.274, 0.782)	0.130	4.073

4.4.5. The effect of respondent characteristics on the predictive ability of the ordinal regression models

We examined whether the addition of certain respondent variables influenced the predictive ability of our two models. To do this, the models were built using just 70% of the dataset. The predictive power of the models was then tested on the remaining 30% of the dataset. In creating the new models, stepwise regression with backwards elimination using 11 additional variables was conducted, as shown in Table 4.8.

Table 4.8. Additional demographic variables and respondent characteristics investigated to improve the predictive performance of the models for perceived biodiversity and perceived naturalness.

	Variable	Data type
1	Age	Numerical: Year of birth
2	Gender	Nominal: Male or Female
3	Highest level of formal education attained	Nominal: five categories, e.g. “Year 11 or below”, “Postgraduate degree”, etc.
4	Frequency of park visitation	Ordinal: 7-point scale from “daily” to “”rarely”
5	History of conservation experience (through work, education, volunteering)	Nominal: “Yes”, “No”, or “Unsure”
6	Perceived knowledge of biodiversity	Ordinal: 10-point Likert scale
7	Perceived importance of biodiversity to human health	Ordinal: 5-point Likert scale
8	Connectedness to nature	Numerical: Score from the Nature Relatedness Scale (Nisbet et al., 2009)
9	Ecology-related words known	Numerical: number of selected words from a list of 13 words that the respondent would feel “confident explaining the meaning of to another person.”
10	Consequences of biodiversity-loss known	Numerical: Number of “consequences of biodiversity loss” the respondent selected from a list of six consequences containing four correct, and two incorrect choices.
11	LGA of residence	Nominal: LGA name

There was a marginal improvement in the predictive power of the “perceived biodiversity” model by incorporating the variables: “highest level of formal education attained” and “ecology-related words known”. With the addition of these two respondent attributes, the Nagelkerke R-squared increased to 0.347 (from 0.307); the AIC decreased to 1723.4 (from 2327.4); and the BIC decreased to 1786.9 (from

2368.2). Although these results show that the inclusion of variables related to education and perceived knowledge improve the model, there was only a 27.6% agreement between the two groups in the split dataset (Kappa = 0.225). This seems consistent with the expected ability of the model based on the Nagelkerke R-squared value. However, whilst it demonstrates that the inclusion of variables related to respondent knowledge can improve the predictive power of the model, it also shows that vegetation cover and the UPNI are still responsible for the majority of this predictive power. Secondly, we cannot ignore that more than 70% of respondent perceptions are not explained by our assessment tools, nor by a whole host of respondent attributes.

An improvement in the predictive power of the "perceived naturalness" model was attained by including "ecology-related words known", "consequences of biodiversity-loss known" and "perceived importance of biodiversity to human health" in the model. With these three variables included, "habitat heterogeneity" became significant, and replaced "bird species richness", which was no longer significant. With the addition of these three respondent attributes, and inclusion of "habitat heterogeneity" the Nagelkerke R-squared increased to 0.381 (from 0.293) and the AIC decreased to 1650.4 (from 2318.8). Despite this improvement, the new model (developed using 70% of the dataset) was able to predict just 30.6% of respondents' perceptions of naturalness in the remaining 30% of the dataset (Kappa = 0.279).

4.5. Discussion

In an increasingly developed world, urban parks are the settings that will help inform urban peoples' attitudes towards nature, and shape the standards by which they evaluate environmental degradation (Miller, 2005). Furthermore, as centres of commerce and politics, it is in urban areas that policies affecting environments far beyond the urban boundary will be debated and decided (Dearborn and Kark, 2010), highlighting the importance of understanding the values and benefits urban people derive from important ecological concepts such as biodiversity. Our results suggest a disparity between the

way people perceive environmental attributes, and objective measures. The following section discusses the results and implications of these findings.

4.5.1. Associations between park attributes and park size

The results showed a very weak association between park size and perceived biodiversity. Park size was moderately correlated with several variables, namely, anthropic element diversity, habitat heterogeneity, and bird species richness. It is logical that larger parks are able to accommodate a greater variety of recreational facilities, such as playgrounds and walking trails, so this correlation is unsurprising. Similarly, larger natural environments are known to sustain greater species diversity (Arrhenius, 1921), an ecological principle known as the species-area relationship. Historically, this relationship resulted in most conservation efforts being directed to large tracts of protected land with little consideration of the conservation value of urban parks (Nielsen et al., 2014). Interestingly, the weak relationship between park size and structural heterogeneity, and the very weak relationship between park size and naturalness, illustrates that small parks are still of value from a conservation perspective, as these attributes were not found to be size-dependent. As a society we should not disregard the potential role of small urban parks, but rather, give careful consideration to their content and design, not only as a reflection of their importance to the people who access them, but also to conservation outcomes.

4.5.2. Predicting public perceptions of biodiversity and naturalness

Perceived biodiversity and perceived naturalness were most strongly correlated with vegetation cover, when examined using individual assessment tools. This may indicate that laypeople simply perceive more vegetation as being more biodiverse, and perhaps lack the ability to differentiate between species. It would be of interest to explore

whether homogenous but highly vegetated environments, such as plantations, are still perceived as biodiverse and/or natural. Previous research highlighted this lack of ability to perceive different species (Jorgensen and Gobster, 2010, Fuller et al., 2007), and hypothesised that structural heterogeneity would be most strongly correlated with perceptions of biodiversity. Although there was a strong correlation between canopy cover and structural heterogeneity, structural heterogeneity had a weak relationship with perceived biodiversity and naturalness, suggesting that changes in vegetation structure might still be too subtle for the public to perceive. Shanahan et al. (2015b) found that people with a stronger connection to nature travel further to visit parks with greater vegetation cover, highlighting the importance of vegetation in attracting people to parks. Our results suggest that this vegetation cover might also play a key role in educating visitors about ecological concepts like biodiversity. Should park agencies seek to increase vegetation cover with this objective in mind, they should note that the public may need some support in recognising such changes, for example, Schebella et al. (2017, p. 17) recommend that environmental improvements made by park managers should be introduced in conjunction with programs that encourage park users to take notice of micro-variables and subtle natural processes. Building capacity among visitors to be more observant and understand natural processes can assist in building a society more connected and appreciative of the environment. Importantly, it can also lead to greater support for management changes in parks and awareness of how those changes are often designed to simultaneously improve the environment and the enjoyment of visitors. Biodiversity, similar to climate change, is a very intangible concept for most people. McDonald et al. (2015) contend that this limits the public's willingness to take action, however directly experiencing events such as drought perceived to be related to underlying environmental problems (climate change, in this case), leads to increased concern and action (Li et al., 2011). This further suggests that education programs focusing on connecting people to nature and raising awareness of the ways they would be impacted by biodiversity loss may be effective at prompting conservation action.

The fact that "perceived natural shade cover" was not strongly related to vegetation cover in the present study, also suggests that the public does not consider vegetation

cover to simply be “trees” but also other forms of vegetation that we could not distinguish from trees using i-Tree Canopy. Perhaps the natural structures in our “structural elements” checklist were not visually distinct enough to be an accurate reflection of public perceptions, and a shorter list with more dramatic differences in natural forms should be tested. Alternatively, it is possible that a single representative of a particular element might easily be missed by visitors. The number of each element within green spaces may be of more value (and would also be a better reflection of species richness and evenness), however, also much more time consuming to assess. Studying the ways people move through various park configurations could contribute to understanding why particular park attributes are noticed by the public. While the result may indeed be indicative of people’s inability to perceive differences in natural elements, if the elements that are perceived as contributing to biodiversity are in areas of parks that few visitors see, a weak correlation between structural heterogeneity and perceived biodiversity would be expected. A limitation of this dataset is that self-reported evaluations by park users are assumed to represent perceptions of those parks, rather than small areas within parks they might actually experience. A number of studies have reported that most park visitors do not explore parks to their full extent, (e.g. Meijles et al. (2014) found park visitors stay relatively close to the carpark, and Brown and Weber (2011) illustrate the uneven geographical distribution of visitors in parks). Visitors who remain near the carpark might not experience the structural variation a particular environment has to offer. Biological surveys, even simplified ones as in Tzoulas and James (2010), which employ systematic transects and quadrats to assess environments might also fail to reflect human experiences of natural spaces. Future studies examining human perceptions of environmental attributes will benefit from employing experimental designs in which respondents’ exposure to attributes are controlled and not dependent on their exploration of the park.

By examining differences in the strength of the correlation between each park assessment tool and perceived biodiversity and perceived naturalness, we can see that the simple tools appear to capture the correct ‘type’ of perception, albeit not particularly well. For example, structural heterogeneity, habitat heterogeneity, and bird species richness (more reflective of biodiversity than naturalness) are more strongly correlated

with perceived biodiversity than perceived naturalness. Similarly, anthropic elements, which suggest a human presence in the environment, but not necessarily the destruction or removal of species, has a stronger negative correlation with perceived naturalness than perceived biodiversity. Two tools in the study exhibit a similar strength of correlation with both perceived biodiversity and perceived naturalness, namely, vegetation cover and the UPNI. Further development of the UPNI by incorporating measures of vegetation cover, may result in a stronger tool that better reflects public perceptions of both biodiversity and naturalness.

We sought to determine which tools best predicted respondents' perceptions of biodiversity and naturalness, by creating an ordinal regression model for each perception. Perceived biodiversity was best predicted by a model comprising the UPNI, vegetation cover, and habitat heterogeneity, which together, explained 30.66% of respondents' perceptions of biodiversity. Whilst this is not particularly strong, human perceptions are highly complex, being influenced by an individual's background and past experiences (Kaplan, 1985). Thus, we believe predicting 30% of respondents' perceptions of biodiversity using simple assessment tools is quite significant, not only statistically, but from a park management and design perspective. Furthermore, the results illustrate how small changes to park naturalness, habitat diversity, or vegetation cover have a dramatic effect on predicted biodiversity perceptions. Whether those perceptions of biodiversity then influence visitors' benefits or values, will require further research. Including participant attributes in the model, such as level of education and knowledge of ecology-related words, resulted in a marginal improvement of the model (0.4 increase in Nagelkerke's R-squared). Despite this, it is evident that the UPNI and vegetation cover are the strongest predictors of perceived biodiversity, and attention could be paid to combining the two measures.

Perceptions of naturalness were best predicted by a model comprising the UPNI, vegetation cover, and bird species richness, which together, explained 29.3% of perceived naturalness. Again, the results illustrate how small changes to the park attributes significantly affect public perceptions of important ecological concepts, e.g. the addition of a single bird species increases the odds of a park being in a higher

"perceived naturalness" category by 8.2%. The results suggest that efforts to increase the diversity of animal species in urban parks is likely to have an influence on the public's perceptions of naturalness, but not necessarily on their perceptions of biodiversity, which may be affected more strongly by habitat diversity. The benefit is, improving habitat diversity will likely increase animal diversity. Again, the UPNI and vegetation cover are the strongest predictors of perceived naturalness. While our focus was on easily measurable visual cues such as vegetation cover and structural variation, it may be that colour, scent, or sound are important triggers for people. Grose (2012, p. 162) discusses the influence of plant colour on human experiences, suggesting that colour might be "capable of quietly educating us about the biological diversity underpinning our sense of place." Again, experimental research may provide insight into such cues.

The results indicate that although it is difficult to predict human perceptions of natural environments, there is consistency in the attributes many people use to gauge the state of the environment. Furthermore, they suggest that improving the public's understanding of important ecological principles is likely to strengthen the ability of objective assessment tools to predict perceptions of biodiversity and naturalness. From a park management perspective, park agencies should take care when making changes to urban green space, as the results show that for better or worse, small changes can have a substantial effect on public perceptions of ecological quality. Additionally, although there is some relationship between anthropic element diversity and perceptions of biodiversity and naturalness, the weakness of the relationship suggests that there is capacity to balance recreation and conservation, even in urban parks.

4.6. Conclusion

The pursuit of sustainability requires that urban people, whose values will influence the actions of political leaders, be encouraged to connect with and understand the importance of biodiversity. In this study, objective measures of ecological attributes in 134 urban parks were compared with public perceptions of biodiversity and naturalness. Vegetation cover and the proposed Urban Park Naturalness Index were the strongest

individual predictors of both perceived biodiversity and perceived naturalness. Incorporating respondent attributes related to education and conservation knowledge resulted in only marginally stronger predictions, suggesting we cannot rely on standard educational strategies to improve the public's appreciation of biodiversity. Previous research suggests that structural heterogeneity may be the primary mechanism through which people detect biodiversity, however, in the present study structural heterogeneity was not a significant predictor of perceived biodiversity or naturalness. We suggest that structural differences must be substantial to be detected by the public. Planners should take solace in the fact that park size is not related to perceptions of biodiversity, suggesting small parks can provide the public with opportunities to perceive high levels of biodiversity if they exhibit appropriate attributes, such as significant vegetation cover. Furthermore, the results suggest that perceptions of biodiversity can still be high in green spaces containing a diversity of anthropic elements and recreational facilities. Small changes in park naturalness, habitat diversity, or vegetation cover were found to have a dramatic effect on predicted biodiversity perceptions, and as such, care should be taken to ensure that management actions enhance, rather than impact on these elements. Overall, the findings presented here once again point to a gap between people's perceptions of biodiversity and actual biodiversity. However, they provide insight into how that gap may be bridged and challenge us to explore the cues that influence people's perceptions of this important concept.

Chapter 5. The Nature of Health: a comparison of the wellbeing benefits associated with perceived and measured biodiversity in Australian urban green spaces

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5.1. Abstract

There are few studies examining the wellbeing benefits from exposure to natural environments differing in ecological attributes such as biodiversity, and they have not had consistent results. This study progresses our understanding of the nuanced relationship between nature and wellbeing by analyzing the self-reported benefits derived from urban green spaces varying in a range of objectively measured biodiversity attributes such as bird species richness, habitat diversity, and structural heterogeneity. Respondents' (n = 840) perceptions of biodiversity and naturalness were also examined. We identified the biodiversity attributes most strongly associated with particular benefits, as well as the types of parks where those benefits were significantly more likely to occur. Findings suggest that perceived, rather than objective measures of biodiversity are better predictors of wellbeing benefits. Of the assessed biodiversity attributes, vegetation cover consistently correlated most strongly with psychological benefits. Stress reduction and mood improvement were greatest in nature parks and lowest in pocket parks. Increases in each biodiversity attribute significantly affected psychological wellbeing at different thresholds, suggesting the relationship between biodiversity and wellbeing is not linear. Thresholds of sensitivity for park attributes are discussed, with vegetation cover, naturalness, structural heterogeneity, and park type emerging as the most useful differentiators for studying human responses to nature. Our findings can help inform green space planning to maximize environmental benefits and health benefits concurrently.

Key words

Biodiversity, species richness, perceptions, green space, naturalness, wellbeing benefits

5.2. Introduction

The accelerating decline in global biodiversity is unquestionably one of the most pressing environmental issues of our time. Despite efforts to halt species loss, extinctions are now occurring at an estimated 1000 times the background or 'pre-human' rate (De Vos et al., 2015). Whilst its drivers are many, from pollution to deforestation, ultimately, our collective extinction scorecard speaks volumes about the conservation values held by many modern societies. As Robertson and Hull (2001, p. 971) argue, "conservation goals derive from people's values and beliefs about nature and human society" and thus, species loss may be symptomatic of a growing disconnect between humans and the natural world (e.g. Louv, 2008). Even when the public has a good understanding of environmental issues, the 'psychological distance' between many of these issues and their day-to-day lives limits most individuals' willingness to take action (McDonald et al., 2015). Directly experiencing the consequences of environmental problems is thought to increase concern and elicit behaviour change (Li et al., 2011), however, pre-empting these negative experiences by instead highlighting the ways in which people frequently benefit from positive environmental conditions, such as a diversity of plant and animal species, might also lead to increased advocacy and concern for their protection.

The body of literature supporting a link between nature and psychological wellbeing is extensive, and encompasses a wide range of benefits such as restoration from mental fatigue, improved stress recovery, and positive changes to mood and self-esteem (e.g. for reviews see Keniger et al., 2013, Capaldi et al., 2015). In light of this, researchers have begun exploring whether greater biodiversity has a positive effect on wellbeing (e.g. Lovell et al., 2014), but to date, the results of this research have not been conclusive (see Appendix M). In one of the earliest studies exploring the relationship between biodiversity and self-reported wellbeing, Fuller et al. (2007) identified positive associations between psychological benefits such as "reflection" and plant species richness, and determined that participants were able to detect plant species richness fairly accurately. Self-reported benefits were also associated with bird species richness,

the size of parks, and the number of habitat types they contained. In contrast, when using the same methods as the 2007 study, Dallimer et al. (2012) found no consistent relationship between plant species richness and psychological benefits. They found that benefits increased with perceived biodiversity, however, respondents' perceptions were markedly inaccurate. Further studies have highlighted the inability of laypeople to perceive differences in biodiversity (Lindemann-Matthies and Bose, 2008, Shwartz et al., 2014). More recently, Carrus et al. (2015) found that perceived restorativeness varied amongst four types of green space, ranging from an urban square to a protected area; settings selected because they reflected differences in biodiversity. Carrus and colleagues (2015) did not assess biodiversity perceptions. Also using a typology of three park types, Van den Berg et al. (2014) found no significant differences in perceived restorativeness between differing natural conditions using an experimental design.

Given the results of existing research in this field, it is not yet clear whether a relationship exists between perceived or objective measures of biodiversity and perceived wellbeing. There are several limitations in the extant literature on this topic that point to the need for a more systematic evaluation of the issue: a) not all studies have examined perceptions of biodiversity to test its effects on the benefits derived from nature experiences; b) studies have assessed biodiversity using different methods, ranging from counts of species richness, to structural variation, to naturalness, to broad park types; c) studies have measured different wellbeing outcomes; d) studies have examined relatively few sites, e.g. 15 sites in Fuller et al. (2007); 34 sites in Dallimer et al. (2012); four sites in Carrus et al. (2015) and three natural sites in Van den Berg et al. (2014); and e) there have been few experimental studies controlling for potentially confounding variables such as social interaction during nature experiences.

Different types of urban green spaces, such as sports parks and community parks, are known to facilitate different types of wellbeing benefits amongst park visitors (Brown et al., 2014, Schebella et al., 2017). Furthermore, those different types of green spaces vary in size and shape (Brown et al., 2014) and differ in the ways they are both perceived and valued by the public (Schebella et al., 2017). Although few studies in the biodiversity-human wellbeing literature have used classification systems to differentiate

green spaces (i.e. because the focus has been on specific attributes such as species richness), we believe park classifications are an accessible means of operationalizing findings in this field. Using a simple park typology, Carrus et al. (2015) found differences in the restorative abilities of urban and peri-urban parks of high and low biodiversity. However, visual assessment of the four parks included in that study suggests they also differed in size, canopy cover, type of ground cover, and intended use, which may also influence wellbeing outcomes (e.g. Fuller et al. 2007, Dallimer et al. 2012, Nordh et al. 2009, Brown et al. 2014). Thus, whilst it is useful to know that different types of green spaces facilitate different wellbeing outcomes, it is important that the components of park types in any given classification system be assessed and controlled for when examining the wellbeing outcomes derived from them.

This paper builds on previous work in this area exploring the following:

- The relationship between self-reported wellbeing benefits and objectively measured biodiversity attributes (naturalness, structural heterogeneity, habitat diversity, bird species richness, vegetation cover, park size).

- The relationship between self-reported wellbeing benefits and perceptions of park attributes (perceived biodiversity, perceived naturalness, perceived canopy cover).

- The relationship between self-reported wellbeing benefits and park type.

- The relationship between respondent characteristics, biodiversity attributes, and the attainment of wellbeing benefits.

5.3. Materials and Methods

5.3.1. Study area and scope

This study took place across three metropolitan Local Government Areas (LGAs) in the state of South Australia. The cities of Burnside, Unley, and Mitcham are located close to the state's capital city, Adelaide. They cover an area of 118 km^2 and house approximately 150,000 inhabitants (Australian Bureau of Statistics, 2017d). A database comprising all public green spaces within the study area was created using GIS data obtained from each local government. Green spaces between 0.4ha (1 acre) and 8ha (20 acres) in size were identified, and each one was assessed on-site using a variety of rapid assessment tools. In consultation with local government, we included 13 parks larger than 8ha in the study, as they were known to be popular with the public, to make a total of 134 parks. Following a public questionnaire, parks that were identified by 20 or more respondents were also assessed remotely using i-Tree Canopy software.

5.3.2. Park attributes

On-site assessments of park attributes – including estimates of biodiversity and naturalness – were conducted in 121 urban parks that met the 0.4 – 8ha size criterion (full assessment of the 13 larger parks was impractical due to their size). Naturalness was assessed using the Urban Park Naturalness Index (UPNI), adapted from Machado's (2004) Index of Naturalness. Biodiversity was estimated using structural heterogeneity and habitat heterogeneity checklists, as well as bird surveys. The checklists were modified from existing assessment tools, and were tested for consistency among multiple assessors in 12 urban parks prior to being used at all 121 sites. The assessment tools and on-site assessment procedure are described in Chapter 4. Vegetation cover, as well as impermeable and permeable surface cover was assessed remotely in the 44 most popular parks using i-Tree Canopy software, which was developed by the USDA Forest

Service (www.canopy.itreetools.org/). We sampled a minimum of 500 random points in each park until the standard error for all land feature classes was less than 2%, irrespective of park size.

5.3.3. Perceived attributes and benefits

A mail-back questionnaire was delivered to 4000 households across the three LGAs. Questionnaires were delivered with a reply-paid envelope and a color-printed A3 map highlighting the 134 green spaces in the study (Appendix A). The questionnaire explored a range of issues including respondents' perceptions and use of urban parks; the physical and psychological health benefits they believe they derive from them; and their level of environmental knowledge and nature connectedness. It also included a range of demographic questions. Respondents were asked to select up to four green spaces in their local area they visit, from the list of 134 parks. They then answered a series of questions about the benefits derived from each park, and their perceptions of the physical environment. 'Benefits' questions identified the main benefits respondents believe they derive from visiting each park, as well as the perceived level of physical and psychological benefit attained. Respondents were asked to indicate the effect they believed a "typical visit" to each location would have on their stress, mood, self-esteem, and ability to concentrate, on 11-point scales from 0 "no change" to 10 "a very big improvement". 'Perceptions' questions provided insight into the perceived variety of plant and animal species present at each park, the perceived degree of naturalness, and the perceived amount of canopy cover, answered using seven-point scales.

5.3.4. Data analysis

Wellbeing benefits were measured using 11-point ordinal scales and as such, ordinal regression modelling techniques were first explored as a means of assessing the predictive power of park attributes and perceived park attributes for these benefits. However fundamental modelling assumptions for ordinal procedures were not met. As

such, multiple linear regression was applied, with the wellbeing variables treated as ordinal approximations to continuous variables (DeMaris, 2005). The data supported this approach as the specified criteria for continuous treatment were each satisfied (DeMaris, 2005), namely the sample size was sufficiently large, the ordinal variables each had at least five levels and were not significantly skewed. This approach offers the advantageous preservation of the ordered nature of the data, which would have been otherwise lost through alternative modelling techniques for categorical data, such as multinomial regression. Analyses were conducted in SPSS version 24.

We examined correlations between perceived biodiversity, perceived naturalness, and four wellbeing benefits (self-reported improvements to stress, mood, concentration, and self-esteem). We also examined correlations between assessed green space attributes (naturalness, structural heterogeneity, habitat heterogeneity, vegetation cover, and bird species richness) and the four wellbeing benefits. Following this, we examined which attributes and perceived attributes had the strongest linear relationship with our respondents' wellbeing outcomes through multiple regression.

We asked participants to identify the benefits they believed they attained from a typical visit to each park, from a list of seven potential benefits (Table 5.1). The list was adapted from the 12 benefits used in a study by Brown et al. (2014), which were derived from the Recreation Experience Preference items developed and validated by Driver and colleagues (e.g. Driver and Brown, 1978, Manfredo et al., 1996), and influenced by research conducted in Australian parks by Weber and Anderson (2010). We provided a shorter list of benefits by combining benefits that were similar (e.g. "spend time with friends" and "connect with family" were combined to form the benefit "spend time with friends/family"). As we intended to group benefits into four domains (Table 5.1), as per Brown et al. (2014) and Moore and Driver (2005a), we believed the lack of distinction between related benefits to be a minor loss of data.

Table 5.1. The list of benefits used in the study. Each benefit was classified into one of four benefit domains, adapted from previous research (Brown et al., 2014, Schebella et al., 2017, Moore and Driver, 2005a).

Benefit	Domain
Enjoy scenery	Environmental
Learn about nature	Environmental
Mentally unwind, escape pressures	Psychological
Escape crowds, enjoy solitude	Psychological
Spend time with friends/family	Social
Improve or maintain fitness	Physical
Physically rest/relax	Physical

Green spaces identified by respondents were classified into four types using a modified NRPA park typology (Mertes and Hall, 1996), in the same vein as Brown et al. (2014) and Schebella et al. (2017) (Table 5.2). As in those earlier studies, we made several modifications to the NRPA classification that were appropriate to our study area. Given the number of very small urban parks in the present study, we retained the mini-park classification (now "pocket parks") and combined neighborhood and community parks into a single classification. The NRPA size guideline for a community park is 30-50 acres (12-20 ha), and there were only two parks in the study area within this size range that were not more appropriately classified as another park type. As neighborhood and community parks are largely delineated by size, rather than features or intended use, we chose to combine the two classifications. Further changes include the exclusion of several NRPA park types: private parks and large urban parks, as they were not present in the study area; school parks, as they are often not publicly accessible; and greenways, as the only potential greenway in the study area was comprised of three separate but similar parks that appeared as extensions of the botanic garden they stemmed from. Given they were separated by roads and contained very similar natural features to the botanic garden, we believed they were more appropriately classified as nature parks.

Table 5.2. The park classifications used in the present study, with rationale for changes made to the original NRPA park types developed by Mertes and Hall (1996)

Classification	Description	NRPA classification	NRPA size criteria	Modification rationale
Pocket park	0.4 – 1.99 ha	Mini-park	Between 2500 sq. ft. and 1 acre.	Size converted to metric and minimum size increased to 0.4 ha (4300 sq. ft.) as parks were assessed on-site. Name change reflects terminology used in local community
Community Park	2 – 20 ha	Neighborhood park Community park	5-10 acres 30-50 acres	Community and neighborhood parks were combined, as they are largely delineated by size rather than intended use, and there only two community parks greater than 30 acres within the study area
Sports park	Size variable, dominated by features intended for sports use, e.g. oval, court	Sports complex Special use	At least 25 acres Variable	Sports complex and special use combined to accommodate smaller sports-oriented parks. Name change clarifies that these areas are parks
Nature park	Size variable, natural resource sites, conservation areas, botanic gardens and arboreta	Natural resource areas	Variable	Name change clarifies that these areas are publicly accessible parks
		Greenways	Variable	Excluded. One potential greenway in the study area comprised three small parks, each separated by a road, but in reality appearing as a continuation of a botanic park, and thus classified as nature parks
		School park	Variable	Excluded. Often not publicly accessible
		Large urban park	At least 50 acres	Excluded. Not present in study area
		Private park/ recreation facility	Variable	Excluded. Not present in study area

5.3.5. Respondent characteristics

A total of 840 questionnaires were returned, giving a final response rate of 21%. Respondents were largely female (62%); highly educated (64% with a bachelor degree

or higher); married or in a de facto relationship (74%); and either working full-time (36%) or retired (34%). Although the greatest percentage of respondent households were couples with no children at home (37%), there were also many sole adult households (18%), families with children over 18 years of age (17%), and families with children aged 7-18 years (17%). Respondent ages ranged from 15 to 99 years, with a median age of 59 years (mean 58.31 years). Comparing this to national census data, we can see that despite the large sample size, our respondents are not strictly representative of the populations in the three LGAs, which are younger (median age of 42 years) with a lower proportion of females (52.5% female) (Australian Bureau of Statistics, 2017a, 2017b, 2017c).

5.4. Results

5.4.1. The relationship between self-reported wellbeing benefits and objectively measured biodiversity attributes

In order to examine the relationship between wellbeing benefits (i.e. self-reported improvements to stress, mood, concentration, and self-esteem) and objectively measured attributes associated with biodiversity (i.e. structural heterogeneity, naturalness, habitat diversity, bird species richness, vegetation cover, and park size), we first conducted Spearman correlations between each benefit, and each park attribute (Figure 5.1). All correlations were significant, with the exceptions of those between naturalness and concentration ($p = 0.331$), naturalness and self-esteem ($p = 0.782$), and structural elements and self-esteem ($p = 0.602$), however, those between wellbeing measures and biodiversity attributes were very weak to weak associations. Improvements to stress and mood were correlated most strongly with vegetation cover, however, it was a weak relationship ($r = 0.254$ and $r = 0.239$, respectively).

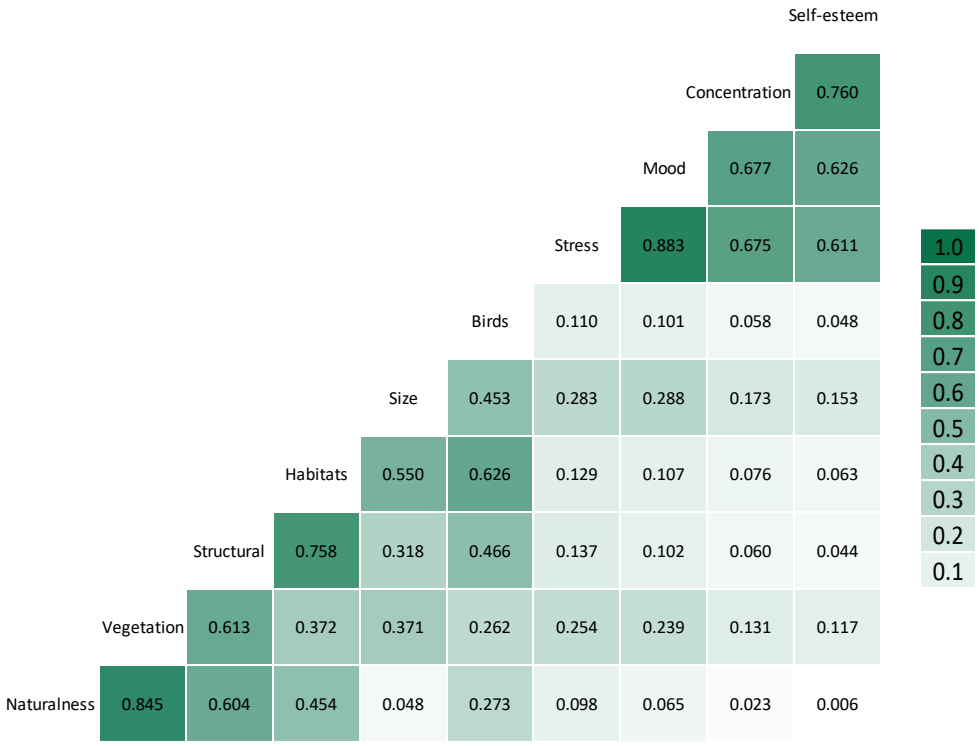


Figure 5.1. Heat map visualization of pairwise Spearman correlation coefficients. Colors represent the strength the correlation between variables. All correlations in the matrix are statistically significant, with the exceptions of naturalness and concentration, and naturalness and self-esteem.

As the assessed biodiversity attributes are not mutually exclusive (i.e. each park exhibits every one of these attributes) we ran a series of separate multiple linear regressions to determine the relative effect of each attribute on wellbeing in the presence of the other attributes. In each regression model, the outcome variable was one of the four self-reported wellbeing benefits. The predictor variables in each model were the biodiversity attributes described previously. We tested for multicollinearity between biodiversity attributes by examining Variance Inflation Factors (VIF) scores. According to Bowerman and O'Connell (1990) all VIF scores in the model should be less than 10 to ensure no multicollinearity. Habitat diversity and naturalness were removed from the models due to multicollinearity, and in the final models, all VIF scores were less than 2. Although we were not analyzing time-series data, respondents were able to report their perceived wellbeing outcomes for up to four parks, therefore, we tested for autocorrelation between residuals using the Durbin-Watson statistic (with a result

between 1.5 and 2.5 showing little-to-no correlation between residuals). There was independence of residuals, as indicated by a Durbin-Watson statistic of 2.02.

The remaining biodiversity attributes significantly predicted self-reported improvements to stress ($F_{4,\ 1395} = 10.443, p < 0.01$), mood ($F_{4,\ 1395} = 6.953, p < 0.01$), and concentration ($F_{4,\ 1387} = 2.551, p < 0.05$), but not self-esteem. The results show that the assessed biodiversity attributes are poor predictors of self-reported wellbeing benefits (Table 5.3). Whilst the predictive power of the models overall is poor – and not unexpected given the weak correlation structure shown in Figure 1 – they still provide insight into the relationships between biodiversity attributes and human wellbeing outcomes. When controlling for vegetation cover, no other biodiversity attribute is a significant predictor of wellbeing outcomes, and on its own, vegetation cover is a stronger predictor of psychological wellbeing ($R^2 = 0.057$) than the combined park attributes model.

Table 5.3. Results of four separate multiple linear regressions. Outcome variables are self-reported wellbeing benefits, and predictor variables comprise structural heterogeneity, bird species richness, park size, and vegetation cover.

Self-reported benefit	R Square	Standard Error	p-value
Improved stress level	0.029	2.866	<0.01†
Improved mood	0.019	2.781	<0.01†
Improved concentration	0.007	3.052	<0.05†
Improved self-esteem	0.004	3.181	0.22

† Significant predictor was vegetation cover

The analysis was extended to examine differences in the attainment of psychological benefits between parks exhibiting very low, low, moderate, and high levels of each biodiversity attribute (Figure 5.3) using one-way ANOVA with Tukey post hoc tests. Each attribute was divided into four equal groups based on the range of values recorded from the biodiversity assessments, as shown in Appendix N. Improvements to

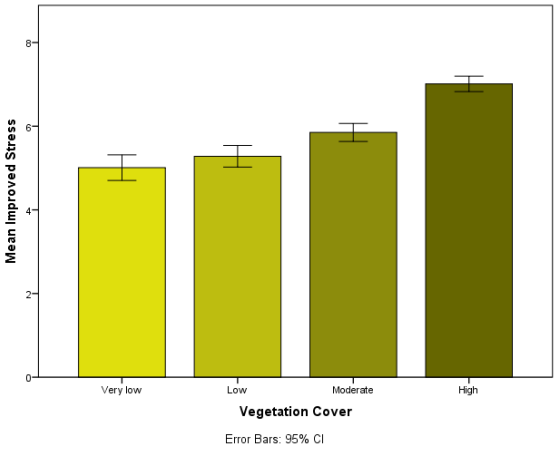
concentration and self-esteem were not included in the tests, because they did not meet the assumption of homogeneity of variances, as assessed by Levene's test for equality of variances (p = 0.027 for concentration and p = 0.019 for self-esteem). Thus, we examined only improvements to stress and mood.

There were statistically significant differences in improvements to stress and mood for all biodiversity attributes, but not between all levels of each attribute (hence the weak linear relationship between psychological benefits and the physical characteristics of the parks). The strongest differences were in vegetation cover ($F_{3, 2322}$ = 57.903, p < 0.001) for stress and ($F_{3, 2325}$ = 53.171, p < 0.001) for mood; structural heterogeneity ($F_{3, 1840}$ = 13.813, p < 0.001) for stress and ($F_{3, 1843}$ = 8.350, p < 0.001) for mood; and naturalness ($F_{3, 1840}$ = 5.521, p = 0.001) for stress and ($F_{3, 1843}$ = 2.972, p = 0.031) for mood.

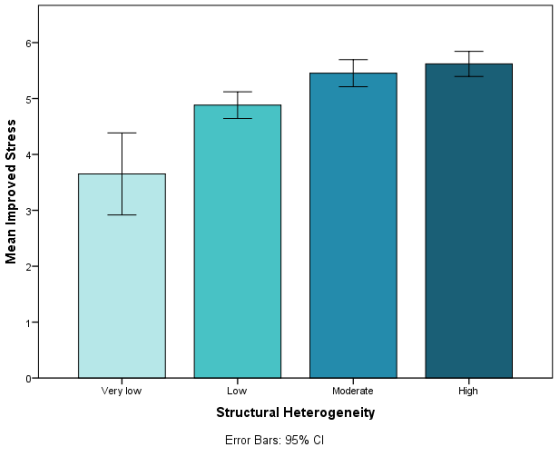
For vegetation cover (Figure 5.3a, Figure 5.3d), significant differences in stress and mood improvement only appear at the highest level of vegetation cover (i.e. benefits are significantly higher in parks with more than 58.71% vegetation cover than in those with less than 58.71% cover).

For structural heterogeneity (Figure 5.3b, Figure 5.3e), significant differences in stress and mood improvement only appear at the lowest level of structural heterogeneity. Benefits are significantly lower in parks with very low structural heterogeneity (i.e. 11 or fewer different structural elements), but there is no significant difference in psychological benefits between parks with low, moderate, or high levels of structural heterogeneity.

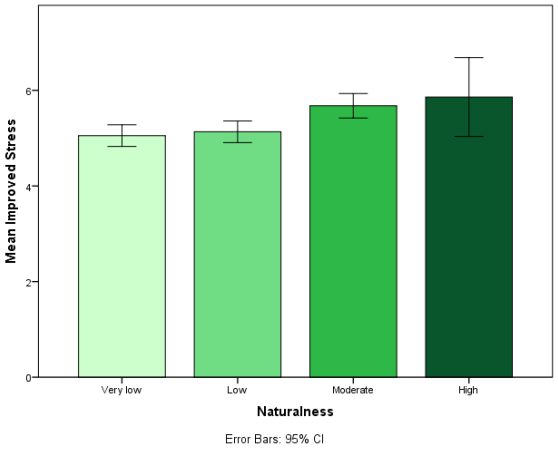
For naturalness (Figure 5.3c, Figure 5.3f), significant differences in stress and mood improvement only appear between the lowest and highest level of naturalness. Benefits are significantly lower in parks with very low naturalness, assessed using the UPNI, than in parks with the highest level of naturalness, but not at the low or moderate levels.



(a)

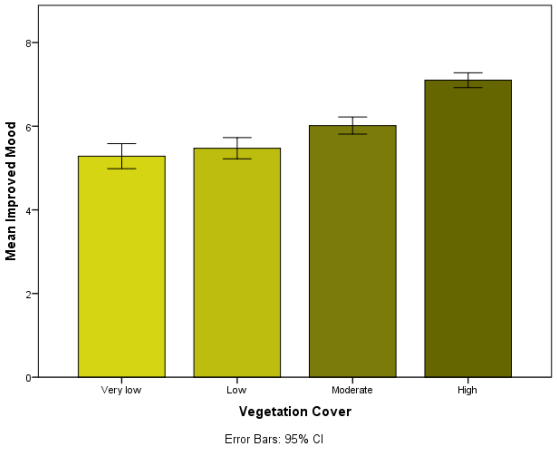


(b)

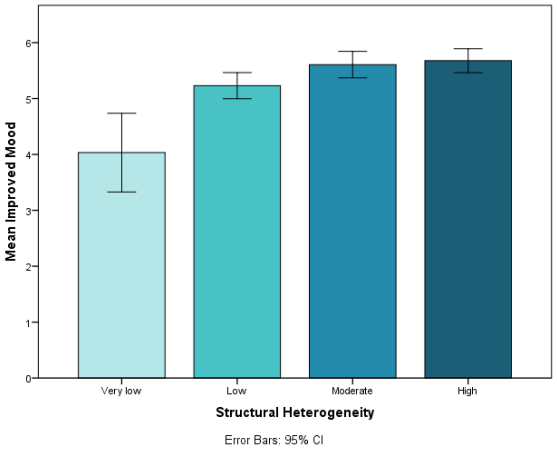


(c)

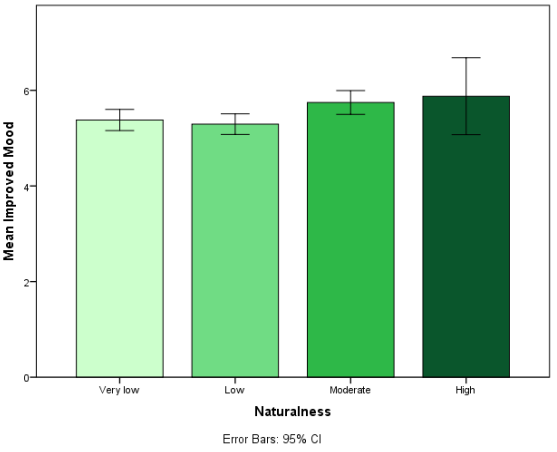
Figure 5.3. Mean improvement to self-reported stress at different levels of (a) vegetation cover, (b) structural heterogeneity, and (c) naturalness



(d)



(e)



(f)

Figure 5.3. Mean improvement to self-reported mood at different levels of (d) vegetation cover, (e) structural heterogeneity, and (f) naturalness.

The analysis was then extended to include a series of categorical analyses to examine the relationship between biodiversity attributes and the main types of benefits (i.e. benefit domains) identified by respondents. We cross-tabulated the main benefit derived by respondents against the physical attributes of each park and examined chi-square statistics and standardized residuals. A standardized residual is calculated by dividing the residual value (i.e. the difference in the observed frequency and expected frequency) by the standard error of the residual. Standardized residuals greater than ±2.0 indicate significantly more or significantly less of a particular benefit than would be expected. As such, they provide a means for assessing the strength of the association between categorical variables. There was a statistically significant association between benefit type and most biodiversity attributes, with the exceptions of habitat diversity and park size, which were not significantly associated with any particular benefit domain. Psychological benefits were disproportionately associated with parks that exhibited high levels of assessed naturalness (χ^2 = 67.49, *df* = 9, $p < 0.001$), as shown in Table 5.4, and high percentages of vegetation cover association (χ^2 = 116.60, *df* = 9, $p < 0.001$), as shown in Table 5.5.

Table 5.4. Park benefits by level of naturalness, showing the standardized chi-square residuals for each benefit domain. Overall association is significant (χ^2 = 67.49, *df* = 9, $p < 0.001$). Standardized residuals greater than +2.0 are shown in yellow and standardized residuals less than -2.0 are shown in blue.

Naturalness	Environmental	Psychological	Physical	Social	
Very low	25.5%	31.8%	37.1%	37.9%	34.9%
	-2.0	-1.1	0.9	1.1	
Low	26.1%	34.8%	32.7%	42.5%	35.4%
	-1.9	-0.2	-1.1	**2.6**	
Moderate	40.5%	28.2%	27.1%	19.4%	26.5%
	3.4	0.7	0.3	**-3.0**	
High	7.8%	5.2%	3.1%	0.2%	3.3%
	3.1	**2.2**	-0.3	**-3.6**	
Total	153	443	617	464	1677
	9.1%	26.4%	36.8%	27.7%	100.0%

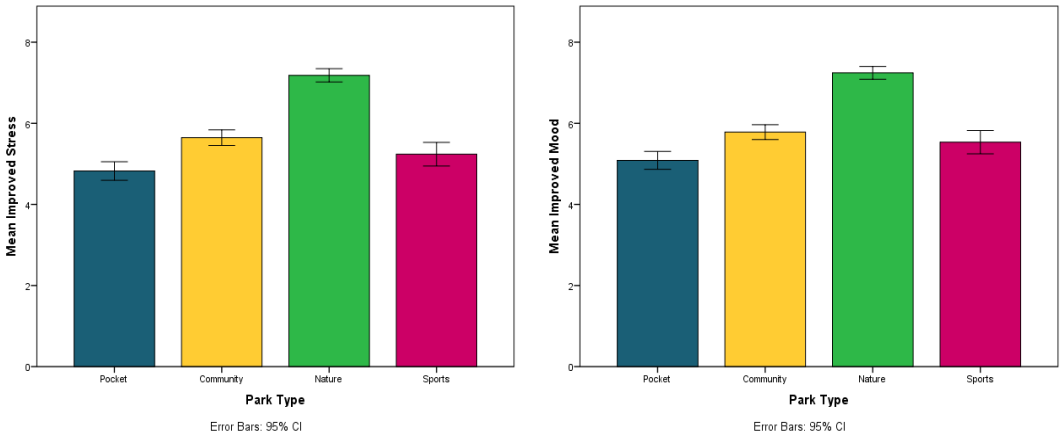
Table 5.5. Park benefits by level of vegetation cover, showing the standardized chi-square residuals for each benefit domain. Overall association is significant (χ^2 = 116.60, *df* = 9, $p < 0.001$) Standardized residuals greater than +2.0 are shown in yellow and standardized residuals less than -2.0 shown are shown in blue.

Vegetation Cover	Environmental	Psychological	Physical	Social	
Very low	4.1%	18.5%	29.7%	25.2%	23.0%
	-4.4	-1.7	**3.0**	0.9	
Low	25.4%	25.9%	22.5%	32.5%	26.5%
	-0.2	-0.2	-1.7	**2.2**	
Moderate	27.0%	29.8%	29.9%	35.6%	31.2%
	-0.8	-0.5	-0.5	1.5	
High	43.4%	25.9%	18.0%	6.7%	19.3%
	6.1	**2.7**	-0.7	**-5.4**	
Total	122	336	462	357	1277
	9.6%	26.3%	36.2%	28.0%	100.0%

5.4.2. The relationship between self-reported wellbeing benefits and park type

A one-way ANOVA was conducted to determine if improvements to stress and mood differed between four types of urban parks: pocket parks (n = 79), sports parks (n = 12), community parks (n = 19), and nature parks (n = 24). Concentration and self-esteem were not analyzed, as they did not satisfy the assumption of homogeneity of variances. There were statistically significant differences in improvements to stress ($F(3, 2835) = 104.523$, $p < 0.001$) and mood ($F(3, 2838) = 93.671$, $p < 0.001$) between park types.

Tukey post hoc analysis shows that improvements in stress and mood are significantly higher in nature parks than all other park types (Figure 5.4a, b), and that stress and mood improvements are significantly lower in pocket parks than in all other park types. Stress and mood improvements in sports parks and community parks were not significantly different.



(a) (b)

Figure 5.4. Differences in mean self-reported improvements to (a) stress and (b) mood between four different types of urban parks.

To identify the most important benefits being attained in different types of urban green spaces, we cross-tabulated benefit type against the NRPA park types, and examined the chi-square statistic and standardized residuals. Psychological benefits were disproportionately associated with nature parks (χ^2 = 133.62, *df* = 9, $p < 0.001$) (Table 5.6), as were environmental benefits. Social benefits were underrepresented in nature parks and disproportionately positively associated with community parks.

Table 5.6. Park benefits by park type, showing the standardized chi-square residuals for each benefit domain. Overall association is significant (χ^2 = 133.62, *df* = 9, p < 0.001). Standardized residuals greater than +2.0 are shown in yellow and standardized residuals less than -2.0 are shown in blue.

Park Type	Environmental	Psychological	Physical	Social	
Pocket	37.1%	37.3%	37.3%	39.4%	37.9%
	-0.2	-0.2	-0.2	0.5	
Community	29.1%	28.2%	27.4%	38.1%	30.7%
	-0.3	-0.9	-1.5	**2.8**	
Nature	27.8%	17.1%	8.4%	1.8%	10.7%
	6.4	**4.0**	-1.7	**-5.7**	
Sports	6.0%	17.4%	26.9%	20.7%	20.7%
	-4.0	-1.5	**3.3**	0.0	
Total	151	426	592	444	1613
	9.4%	26.4%	36.7%	27.5%	100.0%

5.4.3. The relationship between self-reported wellbeing benefits and perceptions of park attributes

In order to examine the relationship between psychological wellbeing benefits (self-reported improvements to stress, mood, concentration, self-esteem) and perceptions of park attributes (perceived biodiversity, naturalness, and canopy cover) we first examined the Spearman correlations between each benefit, and each perceived attribute (Figure 5.5). Although all relationships were significant (p < 0.05) and stronger than those between wellbeing and assessed biodiversity attributes (Figure 5.1), correlations between wellbeing benefits and perceived biodiversity attributes were invariably weak. The four self-reported psychological wellbeing measures were highly correlated with one another. Perceived biodiversity was highly correlated with perceived naturalness.

Of the perceived attributes, perceived biodiversity showed the strongest correlations with all four psychological outcomes.

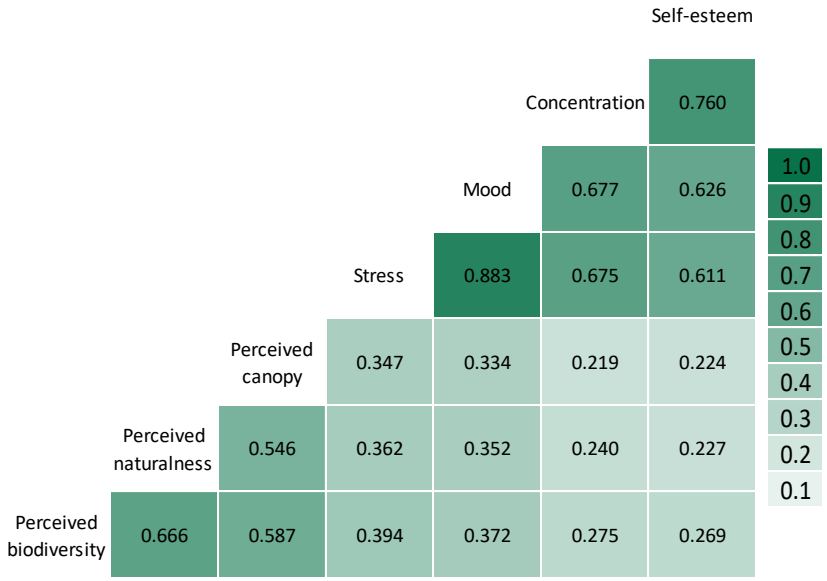


Figure 5.5. Heat map visualization of pairwise Spearman correlation coefficients. Colors represent the strength of the correlation between variables. All correlations in the matrix are statistically significant.

We ran a series of separate multiple linear regressions to examine the relationship between the combined perceived attributes and each wellbeing outcome. The three perceived attributes significantly predicted self-reported improvements to stress ($F_{3,\ 2920} = 196.973$, $p < 0.01$), mood ($F_{3,\ 2916} = 176.502$, $p < 0.01$), concentration ($F_{3,\ 2894} = 87.780$, $p < 0.01$) and self-esteem ($F_{3,\ 2892} = 89.819$, $p < 0.01$), as shown in Table 5.7.

Table 5.7. Results of four separate multiple linear regressions. Outcome variables are self-reported wellbeing benefits, and predictor variables are perceived plant and animal diversity, perceived naturalness, and perceived canopy cover.

Self-reported benefit	R Square	Standard Error	p-value
Improved stress level	0.168	2.712	<0.01
Improved mood	0.154	2.68	<0.01
Improved concentration	0.083	3.054	<0.01
Improved self-esteem	0.085	3.137	<0.01

For each benefit, the strongest individual predictor was perceived biodiversity. When controlling for perceived naturalness and perceived canopy cover, a one-point increase in perceived plant and animal diversity increases self-reported stress benefits by 35.9% (B = 0.359, 95% CI = 0.280, 0.438). Although the model explains more of the variance in self-reported wellbeing benefits than the model comprising only objectively assessed attributes (Table 5.3), it is still not a strong predictor of wellbeing outcomes. Including objectively assessed biodiversity attributes in the perceived attributes model reduced the explanatory power of the model (R^2 = 0.107 for self-reported stress), and furthermore, when controlling for assessed biodiversity attributes, only respondents' perceptions are significant contributors to the model.

5.4.4. The relationship between respondent characteristics, biodiversity attributes, and the attainment of wellbeing benefits

We sought to explore the characteristics of respondents who benefit most strongly from environments exhibiting higher levels of each biodiversity attribute. As the attributes may be suggestive of ecological quality, we hypothesized that including participant

characteristics related to nature connection or knowledge about the environment would strengthen the predictive ability of the park attribute model. We also explored other respondent variables that might influence wellbeing outcomes from park experiences (e.g. age, general health), in order to control for their effects on the relationship between biodiversity attributes and wellbeing benefits. In creating the new model, we focused only on self-reported stress improvement as our outcome variable, as it was explained most strongly by the initial models comprising measured biodiversity attributes. The new base model comprised only vegetation cover, as this was a stronger predictor of stress benefits (R^2 = 0.057) than the model comprising multiple biodiversity attributes (R^2 = 0.029).

To avoid over-saturation of the new model, we initially built five separate linear models, which explored the influence of six different types of participant characteristics on self-reported stress improvement: demographic variables (age, education), health variables (general wellbeing, pre-existing depression, anxiety, and stress levels), surrounding environment variables (perceived number of parks nearby, perceived quality of nearby parks), environmental knowledge variables (formal conservation education or training, knowledge of ecology-related words, knowledge of consequences of biodiversity loss, perceived knowledge of biodiversity), nature values variables (frequency of nature contact, Nature Relatedness Score, perceived importance of biodiversity to human wellbeing), and park use variables (frequency of visiting each park, perceived level of physical benefit from visit). Theoretically, there is support for including each of these variables in a single model, however, there has not been sufficient research to inspire confidence in determining the order (relative importance) of each of them in predicting wellbeing outcomes. Thus, we thought it prudent to model each new variable separately. As shown in Table 5.8, the addition of 'nature values' and 'use characteristics' variables results in the largest increases in R^2 over the original vegetation cover model. However, it is clear that the vast majority of the variance in self-reported stress improvement is not explained by the attributes, perceptions, nor respondent characteristics examined in this study, as R^2 remains consistently low.

Table 5.8. Results of six separate linear regressions. Outcome variable is self-reported stress improvement, and predictor variables comprise vegetation cover and a range of additional variables.

Additional variables included	R Square	Standard Error	p-value
Demographic	0.070	2.825	<0.01
Health	0.086	2.818	<0.01
Location	0.068	2.810	<0.01
Environmental knowledge	0.065	2.768	<0.01
Nature values	0.110	2.727	<0.01
Use characteristics	0.162	2.675	<0.01

In order to determine whether certain variables only become significant in the presence of others, we included all variables from Table 5.8 in a single model. This of course strengthens the model (R^2 = 0.203), however, it represents a substantial increase in complexity for a marginal improvement in predictive power. Modelling all variables together confirms that vegetation cover is still a significant predictor of stress improvement (p = 0.04).

5.5. Discussion

Urban parks were assessed for a range of physical attributes known to be related to biodiversity, i.e. structural heterogeneity, habitat diversity, bird species richness, naturalness (each assessed in situ), as well as vegetation cover and park size (assessed remotely using iTree Canopy software and GIS data). Individually, each of the attributes were weakly correlated with self-reported improvements to stress level, mood, concentration, and self-esteem amongst 840 respondents. Stress improvement, however, consistently correlated more strongly with biodiversity attributes than the other wellbeing outcomes, and vegetation cover was the strongest individual predictor of psychological benefits. Collectively, the biodiversity attributes explained little of the variance in respondents' psychological benefits. Wellbeing benefits were more strongly associated with perceived attributes (i.e. perceived biodiversity, naturalness, and canopy

cover) than objectively measured biodiversity attributes, however, perceptions still explained little of the variance in self-reported wellbeing benefits. Even at the lowest assessed level of any given attribute, or perceived attribute, most respondents still believe that they attain psychological benefits, highlighting the ability of nature in general to improve wellbeing to some extent. Overall, there appears to be a weak linear relationship between biodiversity attributes and the wellbeing benefits included in this study.

The simple and direct measures of wellbeing we included required that respondents be aware of the effects nature experiences have on their psychological and cognitive outcomes, so lack of such awareness may be one reason for the weaker relationships identified in the present study than in Fuller et al. (2007). Frequently used measures such as the Perceived Restorativeness Scale (PRS) (Hartig et al., 1997) can be used to assess the likelihood of cognitive restoration, while not requiring that respondents have explicit awareness of that outcome. From a wellbeing perspective, there is little advantage in our approach, however, from a conservation perspective we believe it is important that the public be aware of the benefits they derive from ecological attributes such as biodiversity. There are a multitude of benefits conveyed to humans by biological diversity, however, many of them are imperceptible (e.g. soil organism diversity helps suppress soil-borne pathogens (Wall et al., 2015), but this is unlikely to be appreciated very often by laypeople), and therefore, generating awareness of such benefits would require widespread environmental education or marketing campaigns. In contrast, wellbeing benefits do not need to be taught in order to be perceived by the public. If we are to encourage people to value positive environmental conditions while they are still present, they must have the ability to perceive the conditions we seek to protect, as well as the benefits they derive from them. Research suggests that our ability to accurately detect those conditions may be quite poor (Dallimer et al., 2012, Lindemann-Matthies and Bose, 2008, Shwartz et al., 2014), but that we respond positively when we think they exist (e.g. Dallimer et al., 2012 and the present study to some extent). This may be indicative of an innate emotional connection with nature (e.g. biophilia) in people who have little need to notice or respond to natural features because they live in urban settings. Perhaps we care, but we cannot see. Interpretive

signs (and even simple labels) have the ability to change the way people perceive and react to natural environments (Kaplan and Kaplan, 1989 outline a range of studies to this effect, p. 106-108), however, interpretation is generally reserved for use in National Parks and important ecological areas, and is not commonplace in small urban parks. Wider usage of interpretive techniques may be effective at highlighting the ecological value of everyday natural environments, positively influencing the way they are perceived by the public, and ultimately improving the wellbeing benefits derived from park visits. Future research could explore whether a concerted effort to highlight positive ecological attributes in parks where they are present, might lead to a sense of their absence in parks where they have been lost, or were never designed to exhibit. Perhaps this juxtaposition in one's own neighborhood might help connect the concept of biodiversity loss with life in an urban setting.

Previous studies examining associations between biodiversity attributes and psychological wellbeing (Fuller et al., 2007, Dallimer et al., 2012) identified stronger linear relationships than the present study, however, they focused on the following benefits: reflection ("ability to think and gain perspective"), attachment ("degree of emotional ties with the greenspace"), continuity with past ("extent to which sense of identity is linked to greenspace through continuity across time"), and in Fuller et al. (2007) also 'distinct identity' ("degree of feeling unique or different through association with a particular place"), each of which were adapted from restoration and place attachment research. 'Continuity with past' and 'distinct identity', in particular, are reflective of the construct of place attachment, and as such, highlight clear differences in how we have defined "wellbeing" in our study. While there is no universally accepted definition of the concept of wellbeing, it is frequently used as a synonym for mental health (Atkinson, 2011) and we have adopted a view of wellbeing more closely aligned with the concept of health. Place, as with wellbeing, is difficult to define (Morgan, 2010), and may be viewed "only as a determinant of personal wellbeing" or conversely, as "an expression…of wellbeing in its own right" (Fuller and Atkinson, 2016, p. 3). Although wellbeing outcomes such as psychological restoration are associated with spending time in places one has an emotional connection with (Korpela and Ylen, 2009), we believe unpacking the two constructs may help strengthen our

understanding of the relationship between people and nature. Whilst the benefits studied in Fuller et al. (2007) and Dallimer et al. (2012) were compared with the physical attributes of the green spaces they were derived in, it raises the question of whether respondents who experienced a greater sense of 'continuity with the past' or 'distinct identity' would equally experience those benefits in another environment exhibiting the same diversity of habitats or species, inasmuch as the benefit may have been derived from an "affective bond to a particular geographic area" (Morgan, 2010, p. 12) rather than the physical attributes of the setting.

Attributes such as species richness and naturalness may influence the development of emotional connections to places, in turn influencing wellbeing outcomes. The finding that greater familiarity with an environment may reduce its perceived restorativeness has been related to a decline in the sense of "being away" in agricultural environments that one has experienced many times before (Collado et al., 2016). Dynamic environments exhibiting greater naturalness, wildness, or diversity (i.e. less manicured or controlled environments) are more likely to exhibit visible changes in response to natural processes and seasonal changes than highly managed settings, and as a result may be more likely to facilitate a stronger connection with nature over time than more static environments, i.e. by eliciting an ongoing sense of escape or "being away". Indeed, biodiversity and wildness were some of the most frequently described attributes of 'favorite' natural environments (indicative of an emotional connection to place) in Schebella et al. (2017). Certainly in this study greater psychological and environmental benefits were reported at higher levels of naturalness.

Our categorical analysis showed that the public's sensitivity to variations in biodiversity characteristics is not uniform across all types of attributes. For example, respondents' self-reported psychological wellbeing only changed in response to extreme variations in naturalness (i.e. very low versus high), but respondents did not perceive that slight increases in naturalness would influence the wellbeing benefits they derived from the environment. Similarly, respondents' wellbeing improvements were significantly lower in parks with 11 or fewer structural elements (i.e. very low structural heterogeneity)

than in parks with more than 11 elements, but past this point participants did not respond psychologically to further increases in structural heterogeneity. Respondents were much more sensitive to variations in vegetation cover, perceiving effects to their psychological wellbeing at multiple levels of vegetation cover change. Vegetation cover may be the most obvious visual cue through which individuals detect changes in the environment around them, and may be the key attribute influencing their perceptions of biodiversity (Dallimer et al., 2012), however, it is not necessarily the attribute most reflective of ecological quality (e.g. homogenous plantations will exhibit a very high level of vegetation cover). Nevertheless, it is promising that these differences are detected by the public, and furthermore, that they perceive these changes to have an effect on their personal wellbeing. The differences in wellbeing attainment between park types may also be indicative of respondents' sensitivity to substantial changes in natural settings, with distinct differences in physical attributes between park types.

It has been suggested that the public's ecological literacy should be improved through environmental education, as greater knowledge of the environment may be associated with sustainable behaviours (Pitman et al., 2018), however, it is possible that deriving a high level of benefit from nature will also influence one's willingness to engage in pro-environmental behaviours. Our results showed that individuals' understanding of the natural environment made little difference to the benefits they derived from it, with most people deriving benefits irrespective of their understanding of concepts related to ecology or biodiversity. Furthermore, research has shown that even those who value biodiversity and believe it benefits their wellbeing, are unable to notice changes in the species diversity of the parks and gardens they visit (Shwartz et al., 2014). Thus, the challenge may lie in strengthening people's perceptive abilities, and not only in teaching them why the environment should be valued. If benefits are associated with perceived biodiversity, those perceptions should ideally reflect actual biodiversity. In fields where observational skills are essential, such as the medical profession, activities prompting people to engage in focused observation have been shown to improve observational skills. For example, visually itemizing the components of, and interpreting the meaning of works of art, has been shown to significantly improve nursing students' ability to identify patient symptoms and suggest alternative diagnoses (Pellico et al., 2009). The

method, which often uses artwork, stems from the idea that "using an unfamiliar object about which the student had no biases and no significant prior knowledge would result in the object being very carefully inspected and every feature reported" (Braverman, 2011, p. 343). How such a technique might be translated to the everyday observational abilities of park visitors will require further research, but once again, environmental interpretation may be one avenue through which this could be achieved. Interventions such as prompting people to notice "three good things in nature" each day, as employed by Richardson and Sheffield (2017) are effective at improving nature connectedness in individuals, and may be adapted for use at a community level through interpretive signs or programs in parks. Such interventions could have a stronger 'observational' rather than 'connectedness' focus by prompting visitors to notice "things that have changed" in the natural environment since their last visit, rather than things that they like. As nature is never static, a heightened ability to perceive natural changes may be quite rewarding and help the public to find continued interest in familiar settings that might no longer elicit strong feelings of fascination or escape.

5.6. Conclusions

Perceptions of biodiversity, naturalness, and canopy cover were more closely related to wellbeing outcomes than objective measures of biodiversity, but the relationship was weak. Of the objectively measured biodiversity attributes, psychological benefits were associated most strongly with vegetation cover, however, variations to naturalness and structural heterogeneity also influenced perceived wellbeing benefits. The public's sensitivity to changes in different physical attributes varied, with even subtle differences in vegetation cover having a significant effect on wellbeing, but substantial differences in naturalness and structural heterogeneity required to have an effect on self-reported wellbeing. The benefit domains associated with particular park types were consistent with previous research, with stress reduction and mood improvement highest in natural parks and lowest in pocket parks. We suggest that attempts to improve the perceptive abilities of park users through interventions or environmental interpretation may result in strengthened wellbeing outcomes and nature connectedness by encouraging individuals to find ongoing interest in familiar natural environments. The relationship between biodiversity and wellbeing is not simple and warrants further investigation of

additional constructs that may affect this relationship. However, it is clear that biodiversity plays a role in wellbeing, and this has important implications to both public health and conservation.

Chapter 6. The Nature of Reality: human stress recovery during exposure to biodiverse, multi-sensory virtual environments – a pilot study

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6.1. Abstract

Immersive Virtual Environments (IVEs) were used to test the effects of biodiversity on recovery from induced stress. Three natural environments and one urban environment were used to represent ordinal levels of biodiversity (none, low, moderate, and high). The four IVEs comprised visual, auditory and olfactory stimuli. An additional high biodiversity IVE without auditory or olfactory stimuli was also added, to study the effects of multi-sensory stimulation *per se* on recovery from stress and perceptions of biodiversity. Following stress induction via a novel IVE Trier Social Stress Test (TSST-IVE), heart rate and five self-reported wellbeing measures were used to assess participants' recovery after immersion in one of the five IVEs. The results showed consistent wellbeing responses across both self-reported and physiological measures, suggesting biodiversity does directly affect human wellbeing. However, the relationship was not linear. For most measures of wellbeing, stress recovery was least effective in the urban IVE, consistent with past research. The low biodiversity IVE elicited the greatest improvement in all wellbeing measures except self-reported calmness. One could speculate that the landscape features of the least biodiverse IVE may elicit subconscious preferences toward savanna-like landscapes, as suggested in previous research. The moderate biodiversity environment was the least restorative of the natural environments, and it is possible that the colors depicted in this IVE were an unintended indicator of ecological quality that may have influenced recovery. A multi-sensory experience was associated with better recovery in all measures of wellbeing than a visual-only experience, and perceptions of landscape components significantly differed between two identical nature scenes when auditory and olfactory stimuli were removed. Nuances in the data and implications of the findings are discussed. The results signal a need for caution. They question the assumption that cultural ecosystem services align with positive outcomes for biodiversity conservation.

Key words

Biodiversity; species richness; virtual reality; stress; experiment; wellbeing

6.2. Introduction

The world might be a better place were it not true, but that which is good for people, is not always good for nature. Although a plethora of research supporting the links between nature and human wellbeing may, superficially, be suggestive of a mutually beneficial relationship, the vast majority of studies have compared the benefits derived from broadly defined 'natural' and 'built' environments, with far fewer studies having examined variations in natural settings, or given consideration to ecological quality or ecosystem functioning (for review see Jorgensen and Gobster, 2010). In fact, most studies in this field have failed to describe the natural environment at all (Taylor and Hochuli, 2017). Despite global initiatives such as "Healthy Parks, Healthy People" we find that comparatively, very little attention has been paid concurrently to the health and resilience of green spaces and the benefits those environments provide to humanity. Indeed, some researchers are concerned that green space has become a commodity, whereby we carefully select the attributes we believe it should contain, based on the benefits we attain from them, and risk creating a "watered-down, biodiversity poor version of nature with compromised ecosystem services" (van Heezik and Brymer, 2018, p. 3). Human-induced change to the natural environment has resulted in unprecedented rates of species loss, estimated to be 1000 times the background or pre-human rate (De Vos et al., 2015). This ongoing decline in biodiversity is expected to carry a multitude of repercussions for our health and wellbeing (Chivian and Bernstein, 2010), largely as a consequence of the declining ability of natural environments to provide provisioning (e.g. food), supporting (e.g. nutrient cycling), regulating (e.g. water purification), and cultural (e.g. spiritual connection to nature) ecosystem services (Millennium Ecosystem Assessment, 2005).

6.2.1. Psychological benefits as an ecosystem service

The psychological wellbeing benefits gained from natural environments are frequently cited as a cultural ecosystem service (e.g. Millennium Ecosystem Assessment, 2005, Sandifer et al., 2015). An important aspect of the widely adopted "ecosystem services" approach to conservation – which focuses on the human benefits derived from nature – is that although it differs from a strict "biodiversity conservation" approach, in theory it will still result in positive outcomes for biodiversity whilst also being accessible to a much broader audience who might not necessarily be concerned with species protection (Ingram et al., 2012). The concern however, is that if psychological benefits are shown to be derived from depauperate environments, then an ecosystem services approach does not serve biodiversity conservation. In such situations, it is vital we acknowledge that the two approaches are unlikely to result in the same outcomes, "so that increasingly scarce resources for biodiversity conservation may be used to target those elements of biodiversity than may not be conserved otherwise" (Ingram et al., 2012, p. 7).

It is therefore crucial to determine if greater levels of psychological benefit are associated with greater biodiversity *per se*. Many wellbeing studies have focused on "parkland with scattered shrubs and trees" (van Heezik and Brymer, 2018, p. 3) and landscape preference research frequently demonstrates that these savanna-like settings are preferred by people (e.g. Hill and Daniel, 2007, Balling and Falk, 1982). Unfortunately, unlike a natural savanna, which may sustain high levels of biodiversity, people's preferences for modified "savanna-like" settings is associated with the clearing of understory vegetation, and presents "a significant obstacle for those seeking to protect biological diversity within ecosystems" (Williams and Cary, 2002). Consequently, it cannot be assumed that classifying nature-derived psychological benefits as a cultural ecosystem service lends itself to biodiversity conservation. Few studies have explored the relationship between biodiversity and psychological benefits directly, and those that have, have produced inconsistent findings. Furthermore, only one experimental study has tested the effects of biodiverse environments on psychological wellbeing (i.e. Johansson et al. (2014), however, Cracknell et al. (2016) also explored this using marine animals in an aquarium setting). The present study seeks

to contribute to this topic by testing whether biodiversity influences recovery from induced stress, using an innovative, multi-sensory Immersive Virtual Environment (IVE) laboratory experiment.

6.2.2. Does biodiversity affect psychological wellbeing?

In their 2010 review, Jorgensen and Gobster noted a dearth of research examining the psychological benefits associated with biodiversity, with only one study having been conducted at that point in time (Fuller et al., 2007). Recent reviews show interest in the topic has grown over the past decade (Aerts et al., 2018, Lovell et al., 2014), however, the results of this research are far from conclusive, and "the topic does not appear to have been addressed in a comprehensive and systematic manner" (Lovell et al., 2014, pg. 5).

Fuller et al. (2007) first identified a positive association between self-reported psychological benefits and plant, bird, and habitat diversity, and further determined that participants were able to detect plant species richness fairly accurately. In contrast, Dallimer et al. (2012) found no consistent relationship between plant species richness and psychological benefits. They found that benefits increased with perceived biodiversity, however, respondents' perceptions were markedly inaccurate. Further studies have highlighted the inability of laypeople to perceive differences in biodiversity (Lindemann-Matthies and Bose, 2008, Shwartz et al., 2014). More recently, Carrus et al. (2015) found that perceived restorativeness varied amongst four distinct types of green space, ranging from an urban square to a protected peri-urban reserve. These settings reflected differences in biodiversity, however, they also likely differed in other attributes (e.g. size, naturalness) and the researchers did not assess biodiversity perceptions. Van den Berg et al. (2014) found no significant differences in perceived restorativeness between three natural conditions using an experimental design to examine the effects of naturalness. The researchers found that perceived naturalness significantly affected perceived vitality, but it had no effect on mood or perceived

restorativeness. Measuring brain activity through quantitative electroencephalography (qEEG), Johansson and colleagues (2014) found that an intermediate level of forest biodiversity was appraised most favorably by participants, followed by high biodiversity, and lastly low biodiversity.

Clearly, the question of whether biodiversity facilitates psychological benefits has not been definitively answered. In examining the existing literature on this topic, Lovell et al. (2014) identified several limitations, including the limited number of studies examining the issue; the heterogeneity of research designs and measures of wellbeing and the environment present in that small body of work; and the inherent complexity in the relationship between biodiversity and human health. In their review, the researchers conclude that there is a lack of evidence as to whether biodiversity is causally related to human wellbeing. Randomized trials are of great value in exploring causality, particularly in a field where the independent variable cannot be experienced in situ in the absence of countless extraneous variables, as is the case with biodiversity. To that end, we conducted a randomized Immersive Virtual Environment (IVE) experiment in which we first induced stress in participants using an IVE Trier Social Stress Test, and examined recovery in three IVE natural environments depicting ordinal levels of biodiversity, as well as one IVE urban environment. In order to increase immersion in the IVE environments, auditory representations of species richness, and increasingly diverse olfactory stimuli were also provided.

Specifically, we sought to address the following research questions:

1. Is stress induced by a novel IVE Trier Social Stress Test (TSST-IVE)?
2. Does recovery from induced stress differ between IVE 'urban' and 'natural' environments?
3. Is stress recovery influenced by biodiversity?
4. Does perceived biodiversity accurately reflect actual biodiversity?
5. Does multi-sensory stimulation affect perceptions of biodiversity?
6. Does multi-sensory stimulation influence recovery from induced stress?

6.3. Methods

6.3.1. Participant recruitment

Participants were initially invited to take part in the experiment via a department-wide email at the principal researcher's institution. In total 52 participants were included in the study. The majority of participants were university staff, but the sample also included undergraduate and postgraduate students, as well as members of the public who had heard of the experiment via word-of-mouth. Twenty-nine per cent of participants had a professional and/or tertiary education background in engineering, 21% in science, 18% in business or administration, 12% in education, and the remaining participants had a range of professional backgrounds including trades, information technology, psychology, and journalism. Potential participants completed an online screening questionnaire to exclude individuals with medical issues such as hypertension, epilepsy, and cardiac health problems. The gender distribution was approximately even (53.8% female, 46.2% male), with a mean age for all participants of 37.6 (SD = 10.6). The screening questionnaire also collected data about participants' current levels of perceived stress using the 10-item Perceived Stress Scale (Cohen et al., 1994), their emotional connectedness to nature using the 6-item short form of the Nature Relatedness Scale (Nisbet et al., 2009), their frequency of nature visits, and an indication of their level of knowledge about ecology and biodiversity. The latter was achieved through two questions: 1) from a list of 13 ecology-related words (e.g. "ecosystem service", "habitat fragmentation") participants were asked to indicate which words they would feel confident explaining the meaning of to another person, and 2) from a list of six "consequences of biodiversity loss" containing three incorrect answers, participants were asked to select which ones they believed were likely to represent future consequences of biodiversity loss.

6.3.2. IVE environments

The Immersive Virtual Environments were 360 x 270 degree videos of real parks located in metropolitan Adelaide, South Australia. All IVEs were filmed on days with similar weather conditions (partly cloudy), and with a slight breeze (to ensure all videos exhibited some movement). They were also filmed at the same time of year (late winter/early spring) to ensure the vegetation, particularly grasses, had not browned off due to dry weather. To ensure the experiment would test the effects of biodiversity (while using real environments and non-manipulated imagery), every effort was put into controlling for extraneous variables in the IVEs. Selection of an appropriate filming location within each environment was based on:

a. On-site assessment of structural heterogeneity using a rapid assessment tool (described in Chapter 4).
b. The absence of people within the scene.
c. The exclusion of elements that were visually inconsistent with the level of biodiversity desired (e.g. although most urban settings contain some vegetation, the selected urban scene did not contain vegetation, to represent a base level of zero species diversity).
d. Similar spatial configurations, (i.e. open, yet defined environments with "relatively smooth ground texture and trees that help define the depth of the scene" (Kaplan and Kaplan, 1989, p. 48)). Although the ground is less smooth in the high biodiversity scene, it is still traversable. The role of "trees" as a spatial element in the urban environment is filled by a tower and tall columns.
e. Similar styles of natural environment, i.e. predominantly native plant species, and not overly manicured (e.g. all exhibit dead/bare patches in ground cover, and do not contain formal garden beds or plantings).
f. The exclusion of animal species in all videos.

The IVEs were filmed using six Xiaomi Yi high definition action cameras (similar to a GoPro), mounted on a 3D printed mount (Figure 6.1) and a monopod. The six individual videos were stitched into a single 360 degree video using Autopano Video Pro software. Participants viewed the IVEs using an Oculus Rift head-mounted display (HMD).

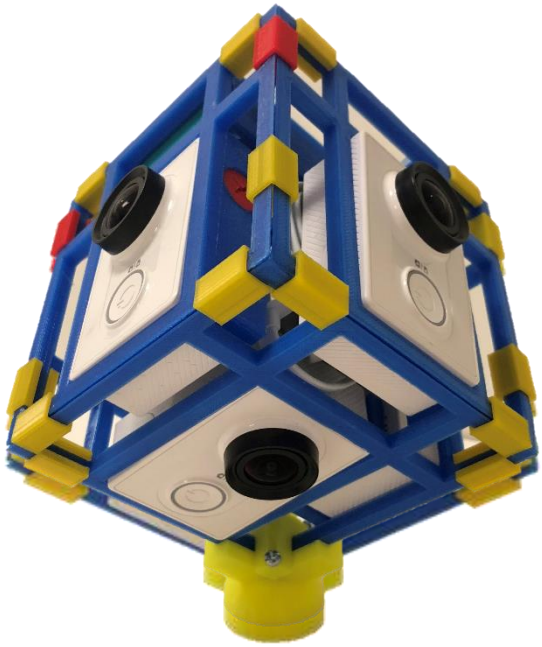


Figure 6.1. The 360 degree camera rig and Xiaomi Yi cameras.

There were five Immersive Virtual Environments included in the study. These are described below and a summary of stimuli used in each is provided in Table 6.1:

Urban: a multi-sensory urban IVE (Figure 6.2a). Care was taken to select a scene that was visually interesting, clean, and exhibited structural variation, as with the nature scenes. It comprised an outdoor shopping mall with *al fresco* dining areas, a tower, and tall signs.

Low: a multi-sensory low biodiversity IVE (Figure 6.2b). This scene consisted of two vegetation layers, i.e. two species of *Eucalyptus* trees taller than 10m high, and ground

layer vegetation less than 10cm high. The total number of structural elements (including non-vegetation elements) was four.

Moderate: a multi-sensory moderate biodiversity IVE (Figure 6.2c). This scene consisted of four vegetation layers, i.e. two species of Eucalyptus trees taller than 10m high, a species of *Acacia* shrub less than 5m tall, small saplings, and ground layer vegetation less than 10cm high. The total number of structural elements was eight.

High-M: a multi-sensory high biodiversity IVE (Figure 6.2d). This scene consisted of seven vegetation layers, i.e. two species of Eucalyptus trees taller than 10m high, a species of *Acacia* tree less than 10m tall, shrubs taller than 5m high, shrubs less than 5m high, small saplings, ground layer vegetation taller than 10cm, and ground layer vegetation less than 10cm high. The total number of structural elements was 15.

High-V: a visual-only version of the high biodiversity IVE, without auditory or olfactory stimulation (Figure 6.2d).

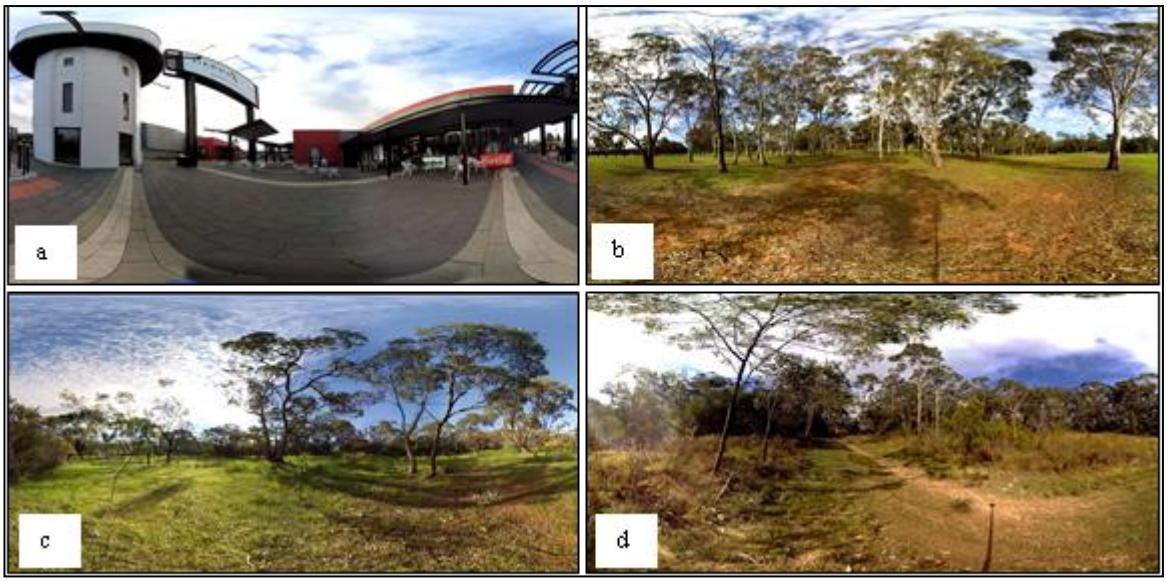


Figure 6.2. Example image of the four IVEs used in the experiment: a) Urban; b) Low Biodiversity; c) Moderate Biodiversity; d) High Biodiversity. Note: as the IVEs are spherical worlds, two-dimensional rectangular images appear warped.

6.3.3. Auditory stimuli

The IVEs were paired with soundscapes that reflected ordinal levels of biodiversity. Soundscapes were recorded using a Zoom H6 recorder mounted on a tripod, with dual microphones (one forward-facing, unidirectional microphone, and one side-facing, bi-directional microphone. The soundscapes were not recorded in the same locations as the IVE videos, with the exception of the urban scene. In order to control for sounds that were not consistent with the environment depicted (e.g. traffic, machinery, people) a base layer soundscape (low biodiversity) was recorded in a rural setting. It contained only "natural" sounds such as birds and the sound of breeze rustling through tree leaves. The soundscape contained a single native bird species, the Australian magpie (*Gymnorhina tibicen*), and this soundscape became the base recording upon which the medium and high biodiversity soundscapes were built. As the ordinal level of biodiversity increased, the base recording was mixed with additional recordings of other

native bird species, such as eastern rosellas (*Platycercus eximius*) and kookaburras (*Dacelo novaeguineae*), so that the high biodiversity soundscape contained the greatest number of bird species. Mixing/layering of recordings was done using Audacity software.

6.3.4. Olfactory stimuli

Due to budget constraints, olfactory stimulation was incorporated through a selection of scents from the Demeter Fragrance Library, rather than through a dedicated scent delivery system. A range of 16 "nature" based scents (e.g. several types of grass, soils, leaves, flowers) and four "urban" based scents (e.g. dust, turpentine) were initially tested on a convenience sample of 11 people, who were asked to describe each fragrance, and the type of environment they believed it was consistent with. Participants were not prompted with scent types or settings, but variations of natural settings (e.g. park, forest, nature) and urban settings (e.g. city, road, machine) were accepted as "natural" or "urban" respectively. Seven scents were correctly identified in type (e.g. grass) and setting by all respondents, and were used in the IVE experiment. Similarly to the biodiversity soundscapes, as the desired biodiversity level increased, so too did the number of scents, which were applied to cotton pads and attached to the head-mounted display during the final phase of the experiment. The urban and low biodiversity scenes contained a single scent, and the high biodiversity scene contained three different natural scents.

Table 6.1. Breakdown of stimuli comprising each experimental condition.

Condition	Vegetation layers	Natural structural elements	Bird species in soundscape	Scents
Urban	0	0	0	1
Low biodiversity	2	4	1	1
Moderate biodiversity	4	8	2	2
High biodiversity (M)	7	15	4	3
High biodiversity (V)	7	15	0	0

6.3.5. IVE Trier Social Stress Test

The Trier Social Stress Test (TSST) (Kirschbaum et al., 1993) is one of the most widely used protocols for inducing psychological stress in laboratory settings. It consists of several stages, two of which involve the participant verbally presenting in front of an audience. Traditionally, the audience in the TSST is a panel of three trained actors, who maintain a neutral expression throughout the procedure. Although the TSST is effective at inducing a stress response, it has several limitations: (1) the cost/logistical difficulty associated with requiring separate rooms for the participant and the audience prior to the speech stages; (2) the human effort involved in having multiple actors present for each participant; (3) the time needed to train the actors to maintain neutral behaviours throughout the TSST; and (4) the possibility that the actors will not behave in the same way for each participant (Jönsson et al., 2010). To overcome these limitations, researchers have begun using virtual reality versions of the TSST (TSST-VR) instead of using a live audience (e.g. Wallergård et al., 2011, Montero-López et al., 2016, Hawn et al., 2015). Most previous versions of the TSST-VR have used a computer-generated virtual audience, which may appear quite artificial to participants. In the present study, we used an IVE version of the panel, as shown in Figure 6.3. The TSST-IVE was a 360 degree video of an oval-shaped lecture hall containing a central stage surrounded by seating on all sides. A panel of three judges was seated in front of the participant, and a larger audience surrounded the participant in 360 degrees (i.e. participants were aware that the audience was also watching from behind them, and they were able to turn in any direction to view those members of the audience.



Figure 6.3. The TSST-IVE used in the study, depicting a real 360 degree audience and a panel of three judges.

6.4. Measures

6.4.1. Physiological data

Electrodermal activity (EDA) and heart rate (HR) were recorded using Empatica E4 wristbands. An earlier version of the wristband is described in Poh et al. (2010). An E4 wristband was applied to each wrist, as EDA signals may be weaker one side of a person's body (e.g. Picard et al., 2015). Although EDA is traditionally measured at the fingers or palms, wrist EDA measurements have been shown to correlate with finger EDA measurements during emotional responses to videos (van Dooren et al., 2012). Heart rate was recorded in beats per minute (BPM) at a rate of 1Hz, and EDA was recorded in microSiemens (μS) at a rate of 4Hz.

6.4.2. Psychological data

Psychological data were measured using separate Visual Analogue Scales (VAS) for perceived stress, anxiety, insecurity, calmness, and happiness. The VAS were 100mm long horizontal lines, with a label at each end, e.g. "not at all anxious" to "extremely anxious". Participants completed the five VAS at the end of each stage of the TSST (i.e. they completed the VAS five times during the experiment). Although multiple-item

scales are preferable, studies have shown that the use of single-item response scales can accurately measure wellbeing, e.g. stress (Elo et al., 2003), anxiety (Davey et al., 2007), and happiness (Abdel-Khalek, 2006).

6.4.3. Perceptions

Perceived "plant and animal diversity" was measured using a five-point scale as well as the four-item Biodiversity Experience Index (BEI) (Gyllin and Grahn, 2005). Perceived "nativeness" of the species in the environment, perceived "beauty", and perceived "weed presence" were also measured on five-point scales.

Participants' sense of presence in the IVEs was measured using a modified version of Kim and Biocca's (1997) telepresence questionnaire. Presence is defined as "the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer and Singer, 1998, p. 225). We modified Kim and Biocca's (1997) telepresence questionnaire by replacing references to "broadcast" or "television" with "virtual environment". We selected this questionnaire as it focused on participants' sense of feeling like they were in the IVE, and did not include questions related to having control over events in the environment such as in Witmer and Singer (1998).

6.4.4. Experiment procedure

Each participant took part in the experiment individually. The experiment closely followed the original TSST procedure (Kirschbaum et al., 1993) and had five stages (Appendix J):

Relaxation

Upon arriving at the VR laboratory, each participant was greeted by two researchers who were wearing white lab coats, as per Kirschbaum et al. (1993). Participants were seated in a waiting area that was partitioned off from the rest of the VR laboratory. Their wrists were cleaned with alcohol, and an Empatica E4 wristband was applied to each wrist. A 15-minute baseline was recorded, after which they completed the first set of VAS (T1). Participants then joined the researchers in the VR lab, where they were asked to sit at a desk that held a computer and an Oculus Rift VR headset.

Anticipation

A researcher explained to participants that they had five minutes to mentally prepare a five-minute speech about their positive and negative personality traits. The participant was told that the speech would be filmed and reviewed by university students who were taking part in a public speaking workshop that semester. A video camera was placed on a tripod next to the desk in view of the participant. The second set of VAS were completed after five minutes of preparation time (T2).

Speech

Participants were told that they should speak about their positive and negative personality traits for the entire five-minute period. The VR headset was put on the participant, and the TSST-IVE began. If participants stopped talking for more than 10 seconds, they were reminded that they should continue speaking for the entire five-minute period. Upon completing their presentation, the VR headset was removed and the third set of VAS were filled in (T3).

Arithmetic

Participants put the VR headset on again, and were asked to count backwards from 1022 in counts of 13. They were informed that if they made a mistake, they would be asked to

begin counting from 1022 again. After five minutes, the headset was removed so that the fourth set of VAS could be completed (T4).

Recovery

In the final phase of the experiment, participants once again donned the VR headset, and spent five minutes in one of the IVEs outlined previously. After the recovery phase, participants were asked to complete the fifth set of VAS (T5), followed by a questionnaire regarding their perceptions of the environment they had experienced.

6.4.5. Data analysis

Data were analyzed using SPSS statistics software version 24. Data screening was conducted to check the suitability of the data for further analysis. At each time point during the experiment, some measures were not normally distributed for at least one IVE group. Therefore, analyses under each objective are comprised of both parametric and non-parametric tests. Inspection of the EDA data revealed that EDA recordings for many participants were incomplete, and EDA data were therefore not included in the analysis. As heart rate was recorded continuously throughout the experiment, analyses were conducted using average heart rate during the final 60 seconds of each experimental phase.

Prior to conducting analyses related to each research objective, we tested whether there were significant differences in each wellbeing measure between the experiment groups at baseline (T1) to support further analysis. In all cases, normality of data was tested using the Shapiro-Wilk test. Baseline comparability between the different biodiversity groups was then investigated using either the one-way ANOVA procedure or the non-parametric Kruskall-Wallis test, as appropriate. Where significant results were obtained from the Kruskall-Wallis test, post hoc analyses were performed using Dunn's (1964) procedure with a Bonferroni correction applied to adjust for multiple comparisons.

At T1, only perceived happiness was normally distributed in all five groups. A one-way ANOVA was conducted to determine if baseline levels of perceived happiness differed between the five IVE groups. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variances (p = 0.941). There were no significant differences in perceived happiness at T1 between the groups ($F_{4,47}$ = 0.10, p = 0.982).

Perceived stress, anxiety, insecurity, calmness, and HR at baseline were not normally distributed in at least one IVE group. A Kruskal-Wallis H test was therefore run to determine if there were significant group differences in the five measures at baseline, with the result shown in Table 6.2. There were no significant differences in median scores between groups at T1 (Table 6.2), suggesting the different biodiversity groups had sufficiently comparable scores at the baseline to support a comparative analysis. Average responses for each group at the five time points in the experiment can be found in Appendix O.

Table 6.2. Kruskal-Wallis results showing no significant differences in wellbeing measures between biodiversity groups at baseline (T1).

Measure	*H*	*Df*	*n*	*p*
Stress	1.189	4	52	0.135
Anxiety	4.987	4	52	0.298
Insecurity	1.619	4	52	0.805
Calmness	1.189	4	52	0.880
HR	1.789	4	52	0.775

Initial checks also showed that were no significant differences in nature relatedness or background stress levels between groups, as determined by one-way ANOVA for the Nature Relatedness Scale ($F_{4,47}$ = 0.497, p = 0.738), and for the Perceived Stress Scale ($F_{4,47}$ = 0.756, p = 0.559).

A brief overview of the statistical tests used in this study is shown under the research questions they addressed:

Research question 1: Because the TSST-IVE, which we used induce a stress response, generates multiple dependent observations, differences in self-reported stress, anxiety, insecurity, calmness, happiness, and HR were calculated subtracting baseline (T1) from the speech phase (T3) of the experiment for each participant. The statistical difference between T1 and T3 was tested using paired-samples t-tests for those measures that met the test's assumptions, namely heart rate, self-reported stress, and happiness. Self-reported anxiety, calmness, and insecurity were analyzed using Wilcoxon-signed rank tests.

Research question 2: In examining stress recovery in "urban" and "natural" IVEs, separate independent-samples t-tests were used for wellbeing measures that met the test's assumptions of normality, no outliers, and homogeneity of variance, namely perceived stress, anxiety and calmness. Where the assumptions of the independent samples t-test were not met, we conducted Mann-Whitney U tests.

Research question 3: To examine the effect of biodiversity on wellbeing recovery, a one-way ANCOVA was used for those measures that met the test's assumptions of normality, no outliers, and homogeneity of variance, namely self-reported stress, anxiety, and calmness). The remaining wellbeing measures were assessed using Kruskal-Wallis H tests.

Research question 4: Perceptions of biodiversity were not normally distributed, thus to compare perceived biodiversity between the four multi-sensory IVE groups (representing ordinal levels of biodiversity), we used Kruskal-Wallis H tests.

Research questions 5 and 6: A Mann-Whitney U test was used to compare perceptions of biodiversity between the visual-only high biodiversity IVE and the multi-sensory high biodiversity IVE. Mean differences in heart rate (HR) between T4 and T5 for these two groups were normally distributed, thus, independent samples t-tests were used. The self-reported wellbeing measures were assessed using Mann-Whitney U tests. Direct comparisons of 'presence' – the feeling of being in the virtual world and not in the real world, was also examined in relation to the influence of multi-sensory stimulation (research questions 5 and 6). As the data were normally distributed and did not contain outliers, differences in presence were compared using an independent samples t-test.

6.5. Results

6.5.1. Psychological and physiological responses to the TSST-IVE

The differences in wellbeing measures between baseline (T1) and the speech phase (T3) for the TSST-IVE were calculated for each participant. Aggregated results are presented as Figure 6.4.

There were no outliers in the differences between scores for stress, happiness, and HR, as assessed by visual inspection of boxplots. The difference scores for each measure at T1 and T3 were normally distributed, as assessed by Shapiro-Wilk's test (p = 0.177 for stress, p = 0.279 for happiness, p = 0.758 for HR). Paired-samples t-tests showed that performing a five-minute speech in front of the IVE audience elicited a significant mean increase in perceived stress and HR, and a significant decrease in perceived happiness, as shown in Table 6.3. There was a large effect size (Cohen's d).

Table 6.3. Paired t-tests results showing significant differences in perceived stress, happiness, and HR as a result of the TSST-IVE.

Measure	T1 mean	T3 mean	Mean difference	95% CI	*t*	*df*	*p*	*d*
Stress	14.381	48.577	34.196	26.714, 41.678	9.175	51	< 0.001*	1.272
Happiness	70.212	49.452	20.760	13.703, 27.816	5.906	51	< 0.001*	0.820
HR	71.604	80.168	8.564	5.586, 11.541	5.775	51	< 0.001*	0.801

*Denotes significant difference (p<0.05).

The differences between T1 and T3 for perceived anxiety, insecurity, and calmness were not normally distributed, as assessed by Shapiro-Wilk's test ($p < 0.05$). Wilcoxon signed-rank tests showed that performing a five-minute speech in front of the IVE audience elicited a significant increase in perceived anxiety and insecurity, and a significant decrease in perceived calmness amongst participants (Table 6.4). Thus, all measures of wellbeing changed significantly after commencement of the TSST-IVE.

Table 6.4. Wilcoxon signed-rank tests showing significant differences in perceived anxiety, insecurity and calmness as a result of the TSST-IVE.

Measure	T1 median	T3 median	Median Difference	*z*	*p*
Anxiety	10.00	48.50	32.75	5.751	< 0.001*
Insecurity	2.75	36.00	24.50	5.730	< 0.001*
Calmness	84.25	49.00	19.75	-5.371	< 0.001*

*Denotes significant difference (p<0.05).

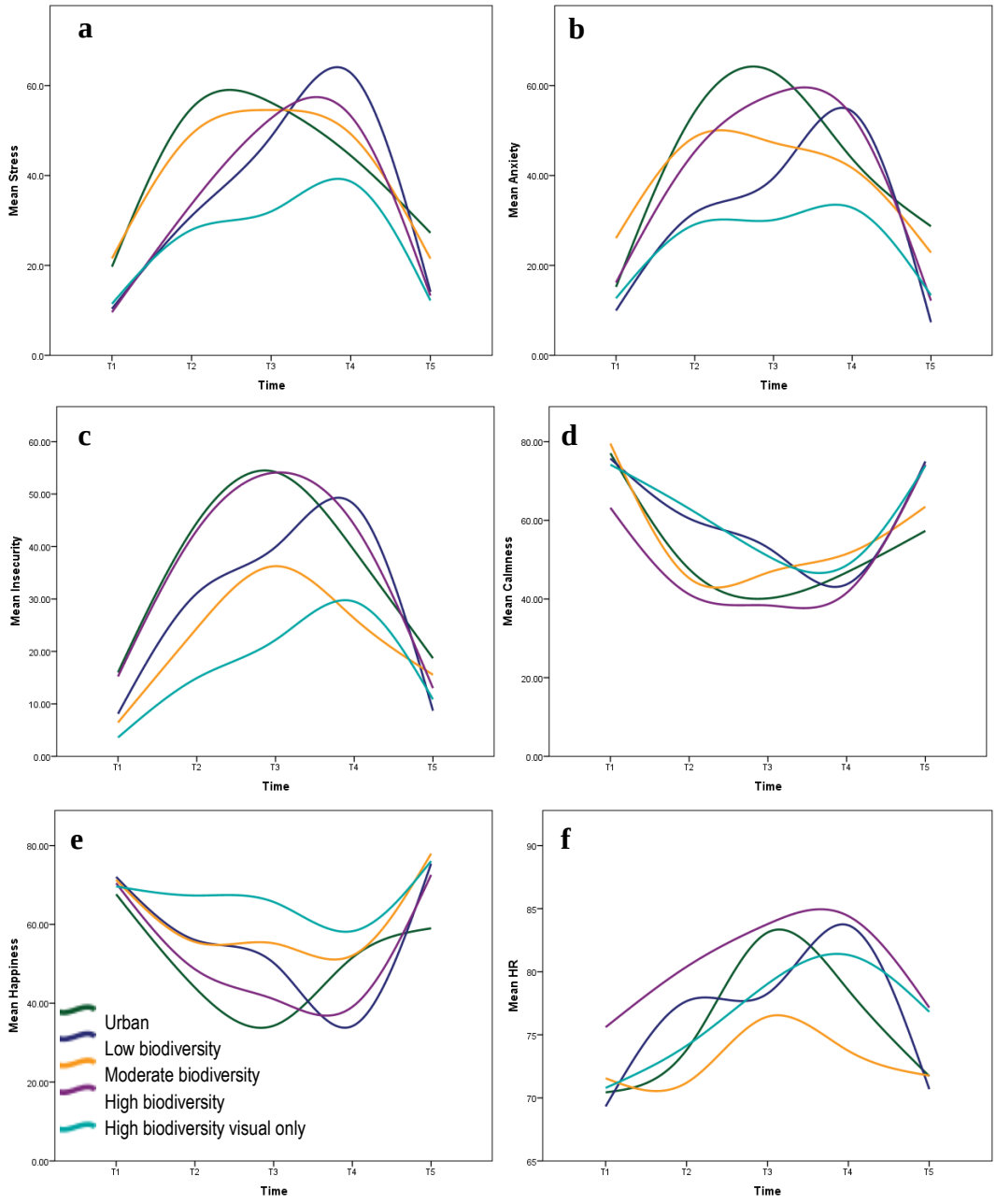


Figure 6.4. Aggregated wellbeing measures over the course of the IVE experiment for (a) self-reported stress, (b) self-reported anxiety, (c) self-reported insecurity, (d) self-reported calmness, (e) self-reported happiness, and (f) heart rate.

6.5.2. Stress recovery in 'urban' and 'natural' IVEs

To determine whether stress recovery differed significantly between the 'urban' IVE and each of the multi-sensory 'nature' IVEs, recovery scores were calculated from the difference in wellbeing responses between T4 and T5.

There were significant differences in recovery between the urban and low biodiversity IVEs for perceived stress, anxiety, and happiness (Table 6.5). There were no significant differences between the urban and moderate biodiversity IVEs, or between the urban and high biodiversity-M IVEs. For perceived insecurity, calmness, and HR, there were no significant differences in recovery between the urban and nature IVEs (Table 6.6). Although most differences did not reach significance, out of 18 paired comparisons between "urban" and "nature" IVEs, the urban group experienced the least effective recovery in 15 comparisons.

Table 6.5. T-test results for the comparison of recovery scores for participants' perceived stress, anxiety and calmness betweeen the urban IVE and each other multi-sensory nature IVEs.

Measure	**Urban mean**	**Low mean**	**Moderate mean**	**High mean**	**Mean difference**	**95% CI**	***t***	***df***	***p***
Stress	17.410	48.630	-	-	31.490	8.214, 54.766	2.842	18	0.011*
	17.410	-	27.690	-	10.550	-15.543, 36.646	0.849	18	0.407
	17.410	-	-	39.945	22.806	-2.395, 48.006	1.894	19	0.074
Anxiety	14.990	46.900	-	-	31.910	5.163, 58.658	2.506	18	0.022*
	14.990	-	18.800	-	3.81	-23.115, 30.735	0.297	18	0.770
	14.990	-	-	41.064	26.074	-2.245, 54.393	1.927	19	0.069
Calmness	10.550	31.240	-	-	20.690	-54.802, 13.422	1.274	18	0.219
	10.550	-	12.000	-	1.450	-31.718, 28.818	0.101	18	0.921
	10.550	-	-	32.618	22.068	-56.496, 12.360	0.196	19	0.189

*Denotes significant difference (p<0.05).

Table 6.6. Mann-Whitney U test results for the comparison of recovery scores for participants' perceived insecurity, happiness, and HR recovery scores betweeen the urban IVE and each other multi-sensory nature IVEs.

Measure	Urban median	Low median	Moderate median	High median	*U*	*z*	*p*
Insecurity	14.500	32.250	-	-	65.50	1.172	0.247
	14.500	-	1.750	-	39.50	-0.794	0.436
	14.500	-	-	16.000	63.00	0.564	0.605
Happiness	7.750	32.250	-	-	19.00	-2.343	0.019*
	7.750	-	12.750	-	30.50	-1.457	0.143
	7.750	-	-	26.500	29.50	-1.796	0.072
HR	6.818	10.795	-	-	58.00	0.605	0.579
	6.818	-	4.029	-	31.00	-1.436	0.165
	6.818	-	-	4.582	51.00	-0.282	0.809

*Denotes significant difference (p<0.05).

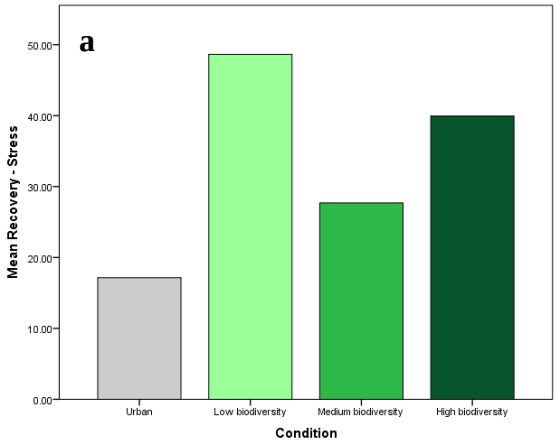
6.5.3. Does stress recovery differ amongst IVEs representing ordinal levels of biodiversity?

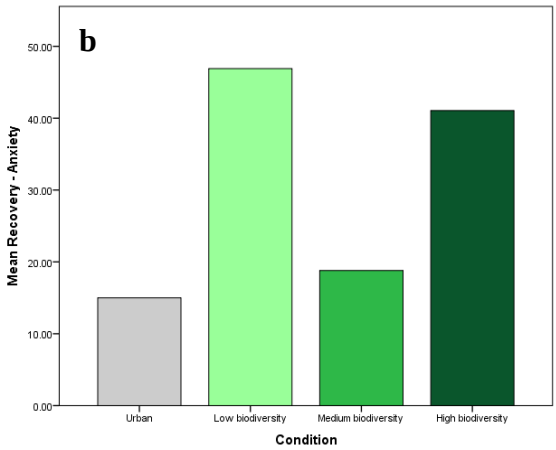
We sought to determine whether there was a statistically significant difference in stress recovery between the three multi-sensory biodiversity IVEs. There were no significant differences in recovery scores for perceived stress, anxiety, or calmness between the low, moderate, and high biodiversity environments (p > 0.05). However, pairwise comparisons using t-tests showed that perceived anxiety recovery scores were significantly greater in the low biodiversity environment than in the moderate biodiversity environment (p = 0.038) (Figure 6.5).

Kruskal-Wallis H tests showed no significant differences in perceived insecurity and happiness recovery scores between the biodiversity IVEs, however, there were significant differences in median HR recovery scores ($\chi^2(2) = 9.234$, p = 0.007) as shown in Figure 6.6. A post-hoc analysis revealed median HR recovery was

significantly greater in the low biodiversity group (20.50 BPM reduction) than in the moderate biodiversity group (10.20 BPM reduction). Thus, there was a significant difference in some measures of stress recovery (i.e. perceived anxiety and HR) between the low biodiversity and moderate biodiversity scenes, with the low biodiversity scene eliciting greater recovery from induced stress in both cases. Of the multi-sensory biodiversity IVE's, the moderate biodiversity environment consistently elicited the least effective recovery.

A one-way ANCOVA was used to examine the effect of biodiversity on recovery scores when controlling for several participant attributes, including nature relatedness (measured using the NRS), knowledge of ecological concepts, knowledge of consequences of biodiversity loss, and general perceptions of day-to-day stress (measured using the Perceived Stress Scale (PSS) in the screening questionnaire). There were no significant differences when controlling for the tested covariates either individually or collectively.





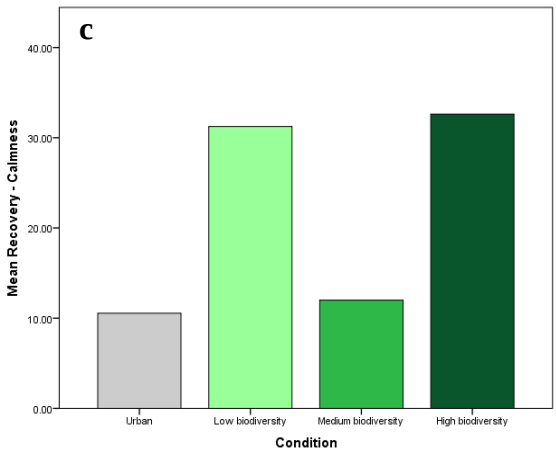
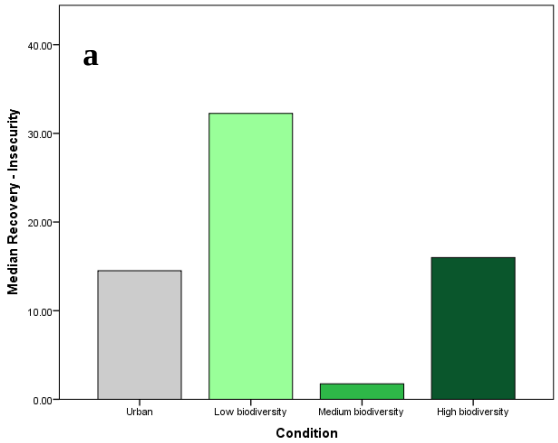
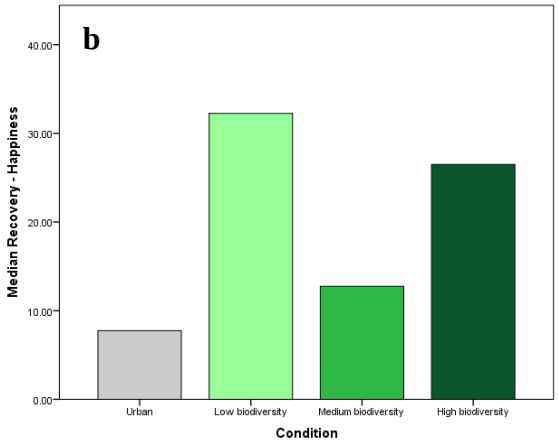


Figure 6.5. Mean recovery scores (from T4 to T5) for (a) perceived stress, (b) anxiety and (c) calmness in the multi-sensory IVEs.





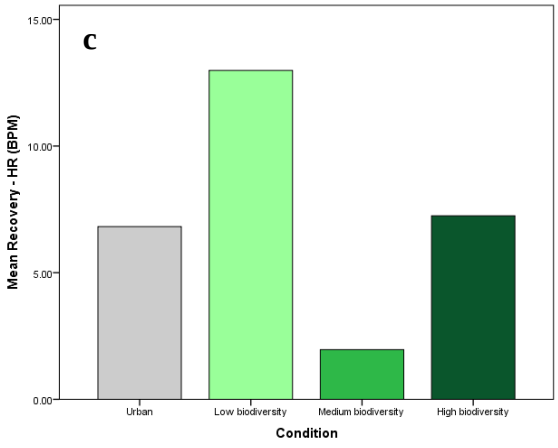


Figure 6.6. Median recovery scores (from T4 to T5) for (a) perceived insecurity, (b) happiness, and (c) HR in the multi-sensory IVEs

6.5.4. Does multi-sensory stimulation influence recovery from induced stress?

Differences in recovery from T4 to T5 between the multi-sensory high biodiversity IVE and the visual-only high biodiversity IVE were examined. Perceived stress and HR were normally distributed in both groups and did not contain outliers. Independent-samples t-tests showed that although perceived stress and HR recovery were greater in the multi-sensory IVE (mean decrease in perceived stress of 39.95, mean decrease in HR of 7.25 BPM) than the visual-only IVE (mean decrease in perceived stress of 26.45, mean decrease in HR of 4.49 BPM), as shown in Figure 6.7, the differences were not statistically significant ($p > 0.05$).

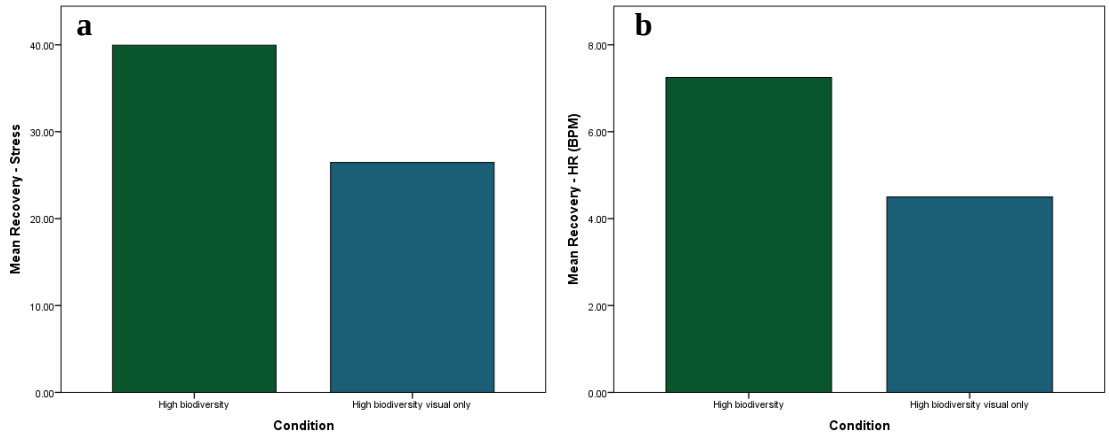


Figure 6.7. Mean recovery for (a) self-reported stress and (b) heart rate, in the multi-sensory high biodiversity IVE and the visual-only high biodiversity IVE.

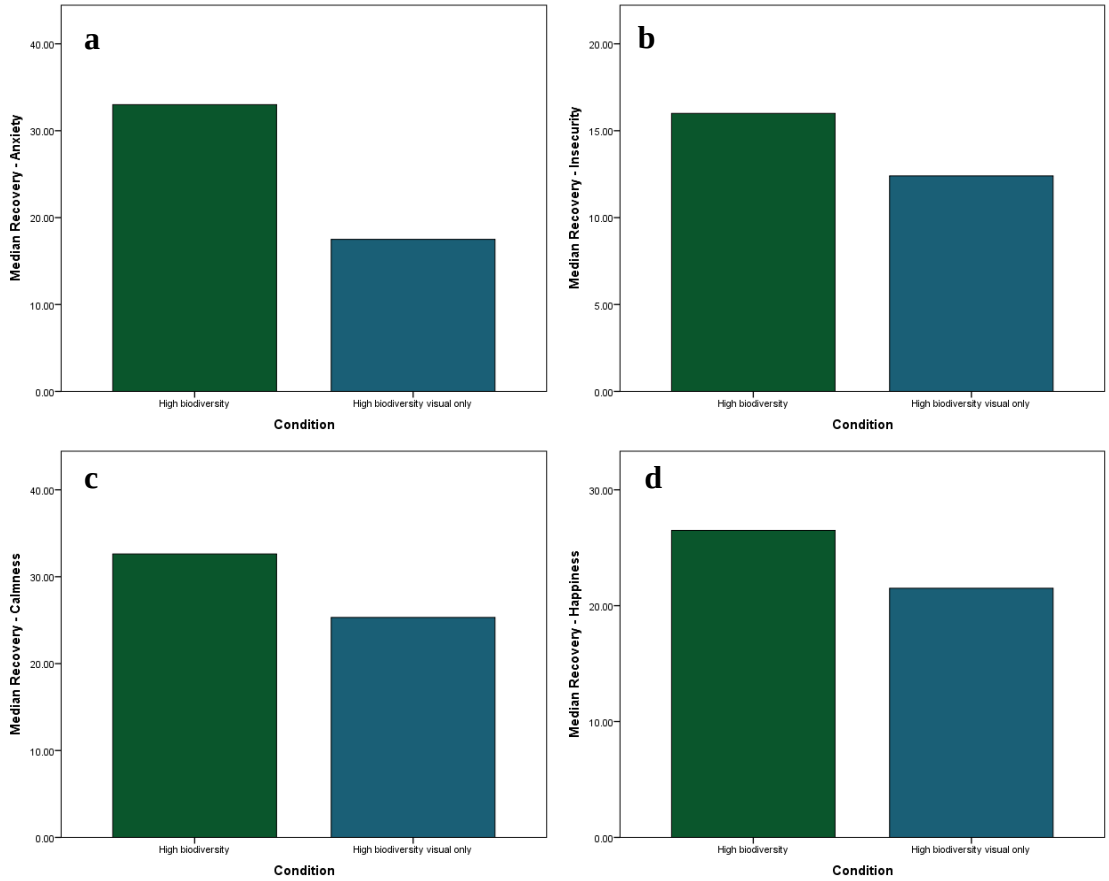


Figure 6.8. Mean recovery for self-reported (a) anxiety, (b) insecurity, (c) calmness and (d) happiness.

Mann-Whitney U tests were used to examine whether multi-sensory stimulation affected recovery scores for self-reported anxiety, insecurity, calmness, and happiness. Median anxiety recovery scores were significantly greater in the multi-sensory high biodiversity IVE (33.00) than the visual-only IVE (17.50), $U = 90.50$, $z = 1.971$, $p = 0.047$. Recovery scores were consistently greater in the multi-sensory IVE than the visual-only IVE (Figure 6.8), however, the difference in recovery was not statistically significant for perceived insecurity, calmness, or happiness ($p > 0.05$).

6.5.5. Influences of environment on perceptions of nature

We explored whether perceptions of biodiversity, nativeness, beauty, and weed presence differed between the different levels of biodiversity. Perceptions were reported using 5-point scales. Biodiversity perceptions were also ascertained using the 4-item Biodiversity Experience Index (BEI).

Due to the non-parametric nature of the data, Kruskal-Wallis tests were employed to test for differences in perceptions of biodiversity, nativeness, beauty and weed presence between the IVEs. All five biodiversity groups were included. As expected, the urban environment was perceived as significantly less biodiverse, less native, and less beautiful than all of the natural environments ($p < 0.01$). Only the BEI scores were found to differ significantly between the ordinal levels of multi-sensory biodiversity (Figure 6.9e). Median BEI scores were significantly different between the three levels of biodiversity, ($\chi^2(2) = 8.576$, $p = 0.014$). A post hoc analysis revealed a significant difference in median BEI scores only between low (2.0) and high biodiversity (3.03).

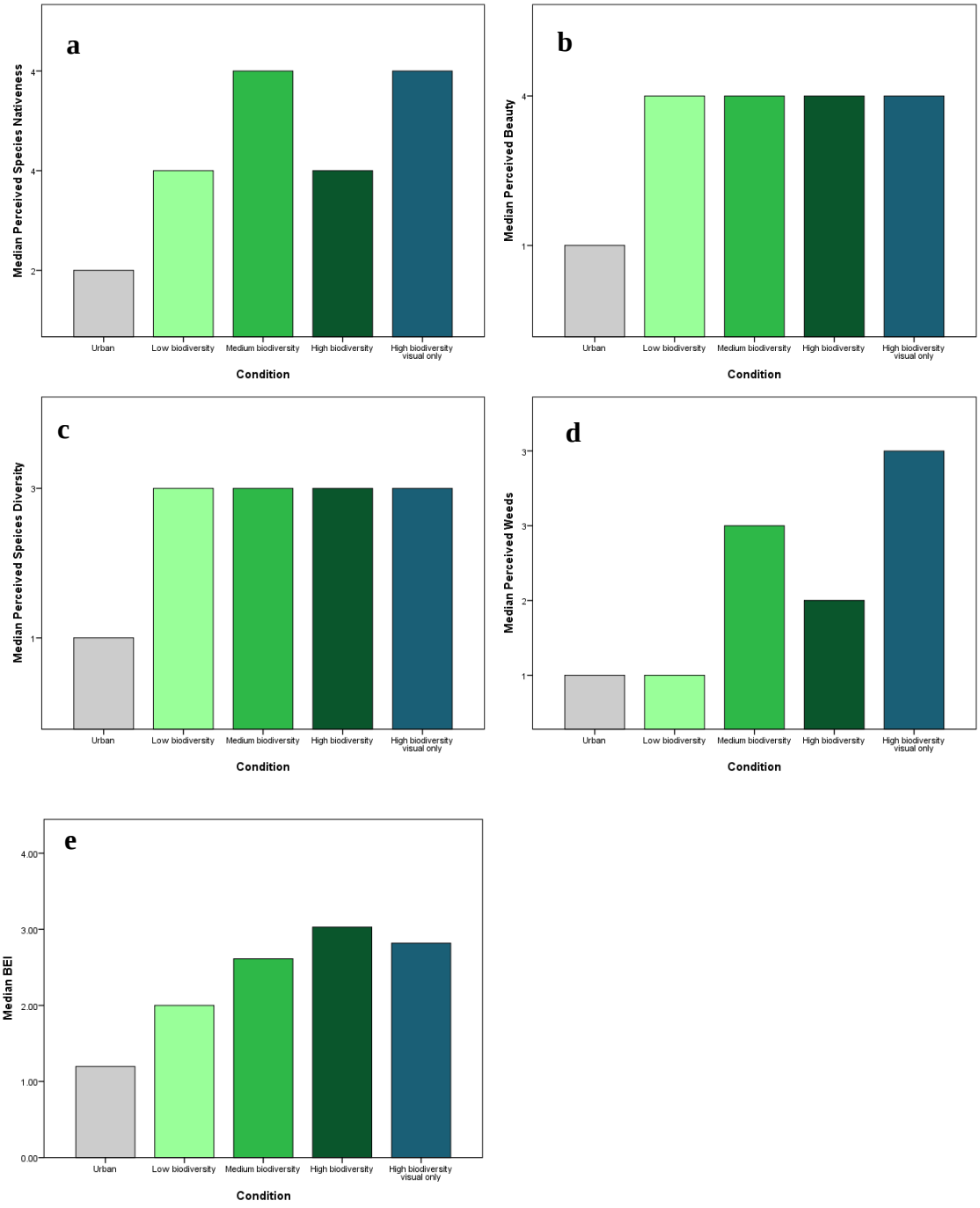


Figure 6.9. Median perceptions of (a) nativeness, (b) beauty, (c) species diversity, (d) weed presence, and (e) BEI in the virtual environments.

Exploring responses to the individual components of the BEI provides further insight into how the IVEs were perceived (Figure 6.10). Interestingly, median perceived animal richness does not differ significantly between the three levels of biodiversity. Animal richness is equally high in the visual-only high biodiversity IVE, in which no animals were depicted (i.e. because the audio recordings provided the only representation of wildlife in the IVEs). Conversely, Figure 6.10a shows perceived plant richness is greatest in the visual-only high biodiversity IVE, suggesting participants may have paid greater attention to the visual attributes of the IVE without the distraction of auditory and olfactory stimuli. The step-wise increase shown in Figure 6.10d suggests perceived "wildness" best reflects the ordinal levels of biodiversity included in the experiment.

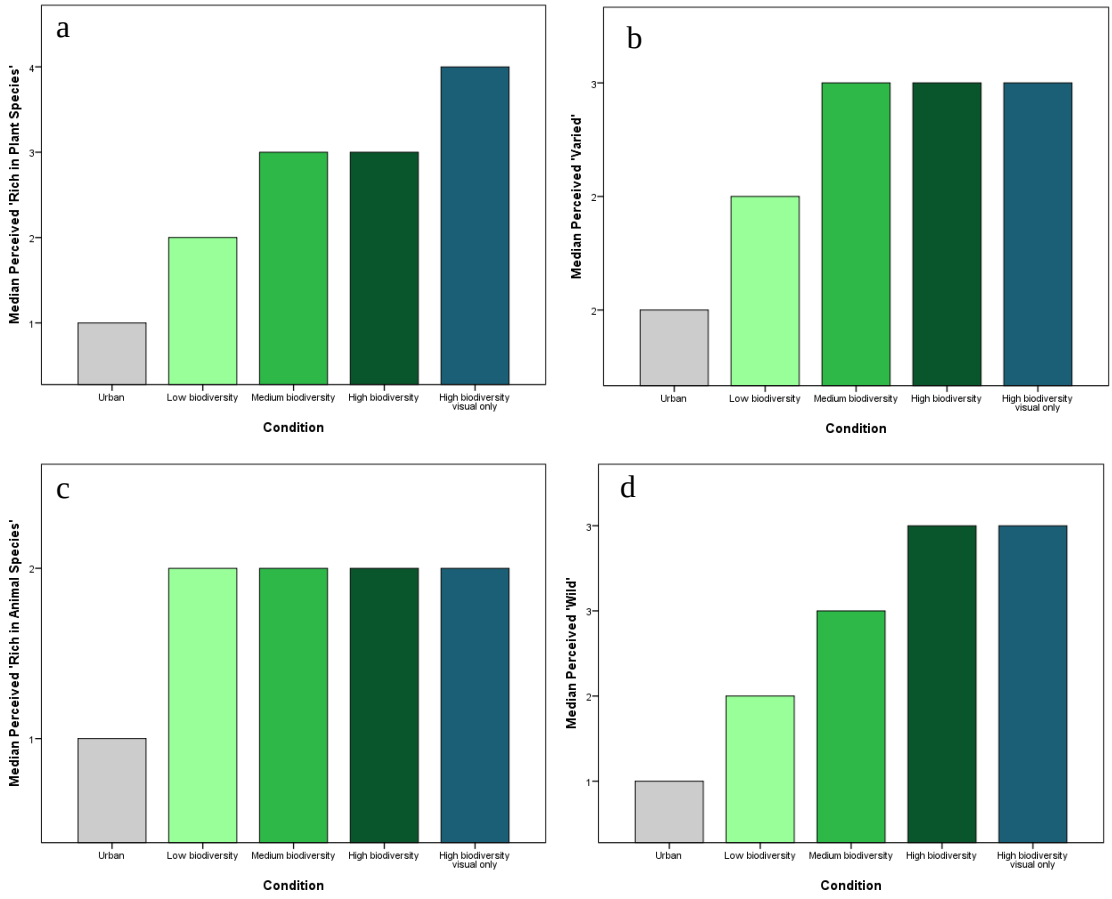


Figure 6.10. Median scores for the individual components of Biodiversity Experience Index (BEI).

6.5.6. Influences of multi-sensory stimulation on perceptions of nature

We explored whether perceptions of biodiversity, nativeness and beauty differed between the multi-sensory high biodiversity environment and the visual-only high biodiversity environment. As the data were not always normally distributed in both groups, we used the Mann-Whitney U test to determine whether there were significant differences in perceptions of the two environments but found no significant differences ($p > 0.05$).

6.5.7. Influences of multi-sensory stimulation on presence in virtual environments

We sought to determine whether this sense of immersion in the IVE was greater in the multi-sensory high biodiversity environment than in the visual-only environment, due to the lack of auditory and olfactory stimulation in the latter group. Presence data were normally distributed for both groups, as determined by Shapiro-Wilk's test ($p = 0.454$ for multi-sensory and $p = 0.087$ for visual-only). A t-test was applied to determine whether mean presence scores differed between the multi-sensory and visual-only high biodiversity IVEs. The results were not significant ($t(20) = 0.095$, $p = 0.925$) and in fact, mean presence scores were almost identical for the two groups, with a difference of only 0.023 (95% CI, -0.477, 0.522).

6.6. Discussion

We conducted an exploratory Immersive Virtual Environment (IVE) experiment to test the effects of biodiversity on recovery from induced stress in 52 participants. Furthermore, we examined whether providing a multi-sensory nature experience affected recovery from induced stress and/or influenced perceptions of natural environments, in order to guide future experimental studies. To our knowledge, it is the first stress intervention trial in this area, and whilst the sample size was small, the results that did reach statistical significance had a large effect size. Some of the finer detail of our exploration did not reach statistical significance, but may arguably have done so with a larger sample size. We believe the consistency in the direction of wellbeing responses across multiple measures, both self-reported and physiological, provides useful insight into the effects of biodiversity on human wellbeing.

6.6.1. The IVE Trier Social Stress Test

The TSST-IVE was effective at significantly increasing heart rate, self-reported stress, anxiety, and insecurity, and significantly decreasing self-reported calmness and happiness. Using the traditional TSST, which is considered by many to be the gold standard in laboratory-based stress inducement (e.g. Allen et al., 2017), was not a financially or logistically viable option for this study. Because researchers are needed to conduct the experiment, and additional staff or trained volunteers are required to play the role of audience/judges, the traditional TSST can be a costly and time-consuming protocol that may be out of reach for small research teams. As such, the TSST-IVE could be a feasible method for future experimental research in nature and wellbeing studies, and can be produced by researchers for their own studies without in-depth knowledge of digital design or computer programing. As described by Smith (2015), IVE technologies are becoming increasingly cost-effective and simple to use.

Examining causal relationships between human wellbeing and nature attributes such as biodiversity will require experimental research, thus, any method that improves the efficiency or ease with which such studies can be conducted is of great benefit to this body of work.

6.6.2. Stress recovery in IVEs

Recovery after the TSST was least effective in the urban IVE for all measures of wellbeing, with the exception of heart rate and self-reported insecurity. The differences in recovery between urban and natural scenes were only significant for self-reported stress, anxiety, and happiness, which showed the greatest improvement in the low biodiversity IVE. There were no significant differences in wellbeing between the urban and moderate or high biodiversity IVEs, however, we consider (a) that the savanna-like landscape of the low biodiversity IVE is most reflective of the natural environments used in much past research comparing wellbeing in urban and natural environments (van Heezik and Brymer, 2018), and (b) despite few significant differences, the urban environment was generally the least restorative environment. In that regard, the findings are consistent with the long-established premise that natural environments are more restorative than built environments and therefore support the use of IVE as a valid and effective approach to measure restoration associated with natural environments.

In all but one measure (calmness), the low biodiversity scene elicited the greatest improvement in wellbeing during the recovery stage. However, the finding does not appear to be related to biodiversity per se, as the moderate biodiversity IVE was invariably the least restorative of the natural environments. There may be thresholds of species richness or structural heterogeneity, above which an environment becomes less restorative, but in that case, one would expect the high biodiversity environment to be perceived as equally restorative as the moderate biodiversity environment, or less so, which was not the case. Furthermore, relative to the other two nature scenes, the biodiversity level (BEI) for the moderate biodiversity IVE was perceived accurately by

participants, suggesting its species richness was not the reason it was responded to so poorly. Although some bird calls may be perceived negatively by people (Ratcliffe et al., 2013), we kept in mind that each bird sound and scent included in the moderate biodiversity experience was also present in the multi-sensory high biodiversity environment, and thus neither auditory nor olfactory stimuli were likely to explain participants' responses. This might be expected given the strong priority placed on visual stimuli in humans (as opposed for example to smell in many animals). Examining the visual components of each of the scenes revealed no particular attribute that we might expect to cause the scene to be responded to as poorly as it was in comparison to the other nature scenes. The scene is a brighter green than the other IVEs, and is the only scene to contain a dense shrub in the foreground. We examined perception responses to shed some light on why the moderate biodiversity IVE was the least restorative. Of the multi-sensory IVEs, the moderate biodiversity environment was perceived as having the most weeds, but also as being the most native. Perhaps it was the incongruence between those two perceptions that led to the scene's lack of restorativeness. Whilst the tree and shrub species present in the scene are all native, the brightness of the ground cover (likely introduced grass species) may be perceived as being at odds with the native surroundings. Grose (2012) suggests that the colour of the natural environments with which we are familiar play a fundamental role in both our sense of place, and in biological conservation. She suggests, "colour can warn us about conservation because we can see it. The colours of our major plant species tell us something about our place, our landscape, our geographic region; the colours are likely to be distinct and different from other places, whether subtly or greatly" (Grose, 2012, p. 161). Again, this is consistent with evolutionary theory, as humans may have evolved color vision to facilitate food finding (e.g. Osorio and Vorobyev, 1996). Thus, our observation that the moderate biodiversity scene was a brighter green than the other nature scenes, and participants' perception that it contained more weeds may be linked. Given that our participants were highly educated individuals, many of whom work in environment-related disciplines, further research would be required to explore whether this seemingly subtle difference in the natural environments would affect other populations as strongly.

Interestingly, the visual-only high biodiversity IVE was similarly perceived to be more native, and to also contain more weeds than the multi-sensory high biodiversity IVE, despite the visual stimuli being identical in both IVEs. In their VR experiment, Annerstedt et al. (2013) found that a VR forest without auditory stimulation (nature sounds) may elicit feelings of uncertainty or unease that limits stress recovery. Similarly, in all measures of wellbeing, we found that participants in the multi-sensory environment experienced greater recovery than those in the visual-only environment. Furthermore, the difference in perceptions of nativeness and weed between the two environments suggests that a visual-only experience may elicit a greater level of scrutiny or visual assessment of the environment than that which occurs during a multi-sensory experience. Without the distraction of sounds and scents, participants may have focused more intently on the physical attributes of the environment, although they were not instructed to pay attention at all. It is of interest to note that perceptions of these ecological qualities differed when participants' attention was focused on a single sense - perhaps being encouraged to take notice of nature, to put aside distractions, can be beneficial from a conservation perspective. However, in terms of wellbeing, soft fascination is thought to be an essential component of restorative experiences (Kaplan and Kaplan, 1989), and the absence of additional sensory stimuli in the visual-only IVE may have resulted in participants not experiencing this effortless attention. Studies testing differences in recovery between participants instructed to take note of natural attributes, and those who have received no instruction, would be of interest in determining whether we can be observant whilst deriving restorative benefits from nature. Ultimately, a population that benefits most from natural environments that they don't pay close attention to may fail to detect ecological change until it is too late. Perhaps our "environmental generational amnesia", wherein each generation cannot see that their environment has degraded from the state it was in prior to their own existence (Kahn and Kellert, 2002) may begin to be stemmed by encouraging simple observation.

One of the strongest findings in this study was the clear appeal of a low biodiversity natural environment. Such an environment was perceived to be equally attractive as the more diverse environments, and was the most restorative during recovery from induced stress. Possible reasons for people's preferences for savanna-like landscapes such as the

low biodiversity IVE are outlined by long-held evolutionary theories such as Appleton's (1975) prospect-refuge theory and Ruddell and Hammitt's (1987) habitat theory. In the present study, the participants in each group expressed a consistently high emotional connectedness to nature, so their responses were not related to their nature values. Furthermore, our participants were highly educated individuals, predominantly consisting of engineers and scientists, and yet, both their self-reported wellbeing and heart rate recovered best in a relatively depauperate environment, which, in reality is a little-used area of incidental green space in an industrial area. Thus, their responses were not related to their knowledge of the importance of complexity or diversity in ecosystems. If we accept that people believe such environments are attractive, restorative, and that they derive the most psychological benefit from them, the question then becomes, what do we do about this? What do we do if human beings take the most pleasure from environments that provide little habitat to native species, are vulnerable to the impact of stressors due to their lack of diversity, and have limited capacity to continue providing ecosystem services to future generations? Would there be a difference if the test could be administered to toddlers (before imprinting with cityscapes as normal, healthy, happy places to be)? Furthermore, what do we do when environmental knowledge appears to have little influence on these perceptions and benefits? The participants in our study, for the most part, understood the importance of biodiversity and ecosystem health, yet derived the greatest benefit from the least diverse and structurally complex environment. Education might not be key to improving perceptions of nature, but it might be key to public acceptance of environmentally-conscious decision-making [e.g. Johansson et al. (2014) found that despite differences in responses to forests with differing levels of biodiversity, acceptance of conservation measures did not differ between environments]. Complexity and diversity are important attributes in many ecosystems, and our decision-making should reflect this, even if such environments are perceived less favorably by the public. The reversal of initiatives designed to increase biodiversity in urban parks has occurred in South Australia as a direct result of public opposition (Gregory, 2003), and clearly, public opinion is a powerful force in decision-making, which cannot be discounted. The challenge lies in balancing those views against the consequences of not taking environmentally-responsible action. In such cases where the two diverge, an ecologically literate public

may be able to support sustainable management and planning decisions in spite of their personal preferences.

6.7. Conclusion

Perceptions of biodiversity, naturalness, and canopy cover were more closely related to wellbeing outcomes than objective measures of biodiversity, but the relationship was weak. Of the objectively measured biodiversity attributes, psychological benefits were associated most strongly with vegetation cover, however, variations to naturalness and structural heterogeneity also influenced perceived wellbeing benefits. The public's sensitivity to changes in different physical attributes varied, with only subtle differences in vegetation cover having a significant effect on wellbeing, but substantial differences in naturalness and structural heterogeneity required to have an effect on self-reported wellbeing. The benefit domains associated with particular park types were consistent with previous research, with stress reduction and mood improvement highest in natural parks and lowest in pocket parks. We suggest that attempts to improve the perceptive abilities of park users through interventions or environmental interpretation may result in strengthened wellbeing outcomes and nature connectedness by encouraging individuals to find ongoing interest in familiar natural environments. The relationship between biodiversity and wellbeing is not simple and warrants further investigation of additional constructs that may affect this relationship. However, it is clear that biodiversity plays a role in wellbeing, and this has important implications to both public health and conservation.

Chapter 7. Conclusions and Recommendations

7.1. Introduction

The overarching aim of this thesis was to explore the nuanced relationship between biodiversity and the wellbeing outcomes derived from nature experiences. Ultimately, this research sought to advance our understanding of how we might balance the health of ecosystems and the health of people in urban areas, a goal that will become increasingly difficult to attain as urban populations continue to grow. A number of knowledge gaps present in the nature and wellbeing literature were identified and addressed, including:

- A dearth of knowledge about the attributes of natural environments required to facilitate wellbeing outcomes, largely due to "environment" commonly being treated as a binary variable in many nature and wellbeing studies;

- The small number of sites that have been examined in existing biodiversity and wellbeing studies, in part due to the time-consuming methods used to assess biodiversity attributes;

- The inconsistency in findings related to wellbeing outcomes derived from ecologically valuable attributes such as biodiversity;

- The geographical disparity in biodiversity and wellbeing studies, with most research in the field having been conducted in the United Kingdom, and to date,

no published studies having examined the benefits of biodiversity experiences at the site-level in Australia;

- A lack of experimental research in the field examining causal relationships between biodiversity attributes and wellbeing outcomes, with no experimental research having examined the relationship between biodiversity and subjective wellbeing.

In exploring this complex relationship, I employed a similar research framework to the one proposed by Shanahan et al. (2015a) (see Chapter 2), by first identifying the attributes of natural environments that are noticed by individuals in valued environments, and examining how they relate to ecosystem health (Chapter 3); developing and utilizing a series of rapid assessment tools for measuring those attributes in urban parks and which were accessible to non-specialists (Chapter 4); investigating whether public perceptions of important ecological concepts such as biodiversity and naturalness are reflected by objective measures of the same concepts (Chapter 4); exploring the association between wellbeing outcomes and both objectively measured and perceived biodiversity, and determining to what extent factors such as nature connectedness and environmental knowledge influence those outcomes (Chapter 5 and Chapter 6).

In this chapter, I briefly summarize and reflect on the results relating to my four research objectives. Following this, I discuss the practical implications of the results for environmental policy and park planning, and make recommendations for future research in this field.

7.2. Summary of findings related to research objectives

The four objectives guiding this research were:

- To determine what ecological attributes people value in their favorite environments and examine the relative importance placed on those attributes in the context of restorative experiences.
- To evaluate whether people's perceptions of the environment reflect objective measures of environmental attributes considered important to ecosystem health.
- To compare the relationship between objectively measured attributes of the environment, people's perceptions of biodiversity and the wellbeing benefits they derive from urban parks.
- To investigate whether there is a causal relationship between biodiversity and wellbeing outcomes.

Objective 1. Determine what ecological attributes people value in their favorite environments and examine the relative importance placed on those attributes in the context of restorative experiences.

I conducted a qualitative exploration of highly valued park attributes amongst 477 South Australians. In Chapter 3, respondents' favorite outdoor places provided a window into restorative environments, consistent with past research (Korpela et al., 2008, Korpela and Hartig, 1996). Without prompting respondents as to the types of responses they could provide, their descriptions of what they "love most" about their favorite places were then used to: identify the most frequently valued attributes of 1,022

restorative environments; classify the most common types of loved environments using a widely adopted park typology; examine the relative importance of setting attributes, benefits, and activities in restorative environments; explore the implications of those values for ecosystem health; and lastly, to ground these descriptions in Attention Restoration Theory (Kaplan and Kaplan, 1989).

Broadly speaking, "nature parks" such as conservation areas and National Parks were by far the most frequently identified loved environments in South Australia, a finding that appears to be consistent with favorite place research in Europe (Korpela and Hartig, 1996). Green space typologies often delineate natural environments based on their intended function (e.g. passive recreation, sport, conservation), and although there is generally overlap between them, the functions these green spaces are designed for result in them exhibiting different physical attributes, promoting different activities, and facilitating different benefits to park visitors. This initial finding suggested there was some characteristic(s) of nature parks that resulted in them being recalled when individuals brought to mind the places that they love above all others. To identify those characteristics, I delved into respondents' descriptions of these environments. I determined whether they related to setting attributes, benefits, or activities, and found that 65% of descriptions related to the physical attributes of favorite places, rather than the activities they allowed for, or the benefits they helped people derive, suggesting a lesser focus on "self" than in past studies of favorite places. Subsequent content analysis highlighted the importance of "fascination" in valued environments over "compatibility" (as per Attention Restoration Theory) – a key distinction from previous studies. I posited two possible reasons for this disparity. Firstly, my study population was substantially older than those in previous studies, and given the described environments were those that respondents had a strong emotional connection with, they may have developed this connection over a much longer period of time than the participants in other research. Hence, their bond with their favorite places was suggestive of "place

1.1 Nature parks were more likely to be valued as restorative settings than other types of green space

1.2 "Fascination" with the physical attributes of natural environments was of greater importance to respondents than "compatibility" between desired benefits or activities and the environment

identity" (emotional attachment) rather than "place dependence" (functional attachment), which were not unpacked in the European or American studies identified in Chapter 3. Secondly, examining the types of physical attributes that were most important to my respondents suggested they may have held a high degree of ecological literacy, e.g. their responses frequently mentioned an affection for attributes such as species diversity and native species. Overall, they placed greatest importance on natural physical attributes such as birds, plants and wildlife, and conveyed an appreciation of natural processes, temporal changes, and dynamic environments, demonstrating an ability to perceive transformation in loved environments.

The importance of setting attributes in the development of place attachment is not a new finding, however, there appears to be little research examining the role of ecological attributes such as biodiversity in the development of such connections. In their 2001 commentary, Horwitz et al. (2001, p. 258) considered the possibility of such a relationship, suggesting that "in order to incorporate sense of place into environmental management efforts, we need to know the degree to which local people incorporate the species, or characteristic features that are unique to their home or place, into their place identity." The results presented in Chapter 3 suggest that such attributes do indeed feature prominently in descriptions of people's attachment to loved environments. In the next phase of my research I examined the extent to which those attributes are perceived in everyday urban parks that are not necessarily "loved" environments.

1.3 Ecological attributes might be of little value in attracting people to green space initially, but may be important to the development of an enduring connection with natural places

Objective 2. Evaluate whether people's perceptions of the environment reflect objective measures of environmental attributes considered important to ecosystem health.

The next stage of my research grew from an acknowledgement that many laypeople would be unable to accurately assess the diversity of biological life in a given environment, based on the findings of previous research (Dallimer et al., 2012, Lindemann-Matthies and Bose, 2008, Shwartz et al., 2014). Building on the idea posited in past research, that attributes such as structural heterogeneity (Fuller et al., 2007) or vegetation cover (Dallimer et al., 2012) may represent distinct visual differences that are more likely to be detected by the untrained eye – yet still be indicative of ecological quality – I developed a series of rapid assessment tools that incorporated the attributes suggested in previous research, as well as ecological attributes pulled from respondents' descriptions in Chapter 3 (e.g. "nativeness" was found to be important, and was incorporated into the UPNI; "birds" were found to be of utmost importance and their diversity was assessed via a bird survey). The assessment tools were employed in 134 urban parks and compared with perceptions of biodiversity, naturalness, and canopy cover amongst 840 South Australians.

The results of this comparison (Chapter 4) showed that the ability of the rapid assessment tools to predict respondents' perceptions was not particularly accurate. Controlling for respondents' knowledge of ecological concepts or understanding of the consequences of biodiversity loss did not strengthen the predictive ability of the tools, which explained approximately 30% of biodiversity perceptions. Similarly, controlling for personal characteristics such as education level or emotional connectedness to nature had little influence on the results. On the one hand, simple tools that explain nearly one third of

2.1 On a whole-park scale, gross visual indicators of ecological attributes in everyday natural environments do not capture the public's perceptions of biodiversity or naturalness

respondents' perceptions of a complex ecological concept may be quite useful, but on the other hand, the result shows quite clearly that most people's perceptions are not reflected by objective measures of a range of ecological attributes when they are examined on a whole-park scale.

The study highlighted the relatively strong influence of vegetation cover on public perceptions of environmental quality, as it was the strongest individual predictor of both perceived biodiversity and perceived naturalness. It is interesting to note, that the strongest explanatory variables for perceived biodiversity (i.e. vegetation cover, the UPNI, and habitat diversity) are primarily planar, mappable attributes, i.e. spatially, they have distinct horizontal dimensions, and they cover a substantial area of a given park, unlike attributes such as structural heterogeneity (vertical structure of the environment) or bird diversity (no spatial dimensions). I did not take this finding to indicate that people cannot perceive the latter attributes in their surroundings, but to suggest a need to account for and understand the ways in which people physically move through environments when we are studying their perceptions or experiences of nature. If structurally diverse vegetation or bird-attracting habitats occur in isolated pockets within parks, or are not dispersed throughout the areas that people experience when visiting, they will not perceive their presence or be able to derive benefits from them. I did not account for this initially, having perhaps incorrectly assumed that respondents would experience the entirety of urban parks given their relatively small size, but in hindsight it is highly probable that visitors will not experience even small parks to their full extent. Principally, examination of visitor movements in parks is addressed only in studies of much larger sites such as wilderness areas, where there is a great need to control visitor movements to minimize crowding, ensure visitor flow, and prevent damage to sensitive resources. I could find no published research examining how people move through comparatively much smaller urban green spaces, likely a reflection of the lack of research attention given to human impacts in these areas, where human impacts are a foregone conclusion. A recent study in Helsinki used GPS tracking through visitor's smartphones to understand movements through an 1100ha urban forest (Korpilo et al., 2018) and

2.2 Vegetation cover has the strongest relationship with perceptions of biodiversity and naturalness

demonstrated that 38% of tracked movements were detected off-trail, with motivations for leaving defined trails including: scenic views, the presence of informal tracks, exploration, and flora and fauna, which is consistent with previous research examining human impacts on the environment (e.g. Wimpey and Marion, 2011). Whilst the parks examined in the present study were far smaller, and not all previously-identified motivations apply to these urban parks (e.g. scenic views), the findings of existing research demonstrate that people have an innate desire to seek out particular natural attributes, and furthermore, that this desire can cause detrimental, visible impacts to the environment. A great deal of research has gone into understanding how we can minimize these impacts in protected areas, for the sake of the environment and the experiences of those who visit, so it seems prudent that we improve our understanding of visitor use patterns in urban parks. Longstanding research demonstrates that visitors will accept extensive signs of management, modification, and human impacts in urban parks (Clark and Stankey, 1979, Brown et al., 1978). Yet, urban parks are frequently designed in such a way that they are robust to human usage, exhibiting characteristics that reflect this level of use, such as hardened walkways and plant species selected for their ability to withstand human impacts (e.g. ground covers are invariably comprised of a rigorous introduced grass that is much more resilient to foot-traffic than our increasingly rare Australian native grasslands). Such attributes may take much longer to exhibit signs of human impacts than more vulnerable natural features such as dirt trails and native grasses. Taken together, the findings of the past and present research presented here, hint at an opportunity for urban green space:

a) Park visitors desire and seek out attributes such as flora and fauna (i.e. in the aforementioned visitor movement studies, and demonstrated in the value placed on micro-variables such as birds and wildlife in Chapter 3), so much so that they will leave defined trails and explore the environment if they feel it provides for such attributes;
b) Park visitors' ability to perceive environmental change is evident in environments they value (Chapter 3), and is strongest in planar elements that are traversed over, beneath, or through (e.g. habitat diversity and vegetation cover) (Chapter 4);

c) Park visitors' actions can have a visible impact on the natural environment *when* those settings are not devoid of their naturally vulnerable attributes (e.g. "soft" trails);
d) Urban park visitors will accept a greater level of human impact than they would in a wilderness park, yet the attributes of urban parks prioritize physical robustness in order to minimize such impacts.

If urban parks were allowed to exhibit many of the naturally vulnerable attributes that are valued in large nature parks, visitors' use and exploration of these attributes could be used to quietly educate the public about the environment and their impact on it, not through intentional degradation, but as a result of their innate curiosity. If we, in an attempt to prevent environment degradation, remove the very attributes of nature that people value and seek out when they have the opportunity to do so, we have prevented the very processes through which they might observe and respond to ecological change in familiar environments. Ultimately, whilst we might despair that humanity is not adequately responding to global environmental issues like biodiversity loss, we cannot expect urbanized people to recognize the loss of something they have not experienced. That is not to say that multi-use urban green space should have a conservation focus – all types of green space have value – but to suggest there is a need and an opportunity to balance ecology and human interests in urban areas.

2.3 Pre-empting degradation in urban parks may unduly homogenize experiences of nature and prevent the public from observing change in familiar environments

The weakness of the relationship between the number of anthropic elements in urban green spaces and the public's perceptions of ecological attributes such as biodiversity and naturalness in the present study, shows that urban recreation sites can exhibit both types of attributes and still be perceived as biodiverse whilst providing for a range of human activities, i.e. the presence of human structures need not detract from perceptions of biodiversity in the context of an urban park. According to Cranz and Boland (2004), over time, urban parks have evolved from "pleasure grounds" with a focus on human

interests, to a new type of "sustainable park" in which human wellbeing and ecological health must be balanced. It would appear that park planning in South Australia has not kept pace with this ideological evolution (likely impeded by funding constraints and a lack of incentives for local Governments to affect change), however, Chapter 5 helps progress our understanding of how human wellbeing and ecological health might begin to be balanced in urban parks.

Objective 3. Compare the relationship between objectively measured attributes of the environment, people's perceptions of biodiversity and the wellbeing benefits they derive from urban parks

This phase of my research (Chapter 5) sought to quantify the subjective wellbeing benefits associated with the objectively measured and perceived attributes that were examined in Chapter 4. Overall, there were fairly weak linear relationships identified between objectively measured biodiversity attributes and wellbeing benefits, and between perceived biodiversity and wellbeing benefits. However, consistent with research by Dallimer et al. (2012), perceptions of biodiversity in the present study were more closely related to wellbeing outcomes than objectively measured biodiversity attributes. In 2007, research examining the links between psychological wellbeing and objective measures of biodiversity was spearheaded by a study conducted by Fuller et al. (2007), who identified a positive relationship between the two concepts. Since this study, research examining the relationship has had inconsistent findings. After examining the supplementary materials provided by Fuller et al. (2007), I suggested in Chapter 5 that the authors' definition and measures of wellbeing appeared to align more closely with the concept of place attachment than that of health, whereas the measures I used reflected the latter. Similarly, studies such as Johansson et al.'s (2014) examination of brain activity, and Carrus et al.'s (2015) examination of perceived restorativeness are not studies of place attachment, but of a health-aligned concept of wellbeing. Neither definition is incorrect, as "wellbeing" is a nebulous

3.1 Previous research may support a link between "place attachment" and biodiversity, but not a health-aligned definition of wellbeing

concept, however, this distinction gives further credit to the idea that ecological attributes are more likely to be perceived in valued environments. Relph (2008, p. 39), suggests, "sense of place also involves familiarity with the physical environment of somewhere – knowing its weather, its seasons, the plants, hills, buildings and streets, and being attentive to changes in them." Relph's statement suggests that this attachment causes people to pay attention to the details of a place they value, which is not in question. It is possible that the relationship is bi-directional however, and that encouraging attention to such features may help one develop and sustain an ongoing interest and care for a particular place. Conversely, if natural environments do not provide for enough dynamic, fascinating qualities, encouraging greater use and familiarity with them may result in a decline in the perceived value of that place. For example, familiar agricultural environments no longer provided a sense of "being away" in Collado et al. (2016) which resulted in a decline in their restorative value. In comparatively small urban parks, this risk may be far greater. The proximity and accessibility of urban parks are known to be important variables influencing the frequency of people's park use, and they have received substantial research attention (e.g. McCormack et al., 2010) and application in planning guidelines (e.g. DPLG 2011). From a pragmatic standpoint, if we are to encourage frequent park use and invest resources in maximizing access to urban parks, we must ensure that those environments can maintain the wellbeing value or interest that the public derives from them, particularly if we seek to encourage an emotional connection or concern for these environments over time. It would appear that achieving this through increasing the diversity of bird species, vegetation structures, or habitats that urban parks exhibit (as natural features are inherently more likely to elicit "soft fascination" than built features (Kaplan and Kaplan, 1989) would be of mutual benefit to nature and human beings.

3.2 Supporting ongoing interest in urban parks may be dependent on providing dynamic qualities that lead to an increase in fascination over time, rather than a decline

Chapter 5 demonstrates that the threshold at which the public's wellbeing is affected by changes in natural features is not uniform across all types of attributes. This finding can be used to prioritize the management of ecological attributes in urban parks, whilst maximizing wellbeing benefits, to those that are most likely to be perceived by the greatest number of visitors, namely: vegetation cover, structural heterogeneity, and naturalness. Although van Heezik and Brymer (2018) argue that green space has become a commodity that is managed only for its human wellbeing benefits, the findings of this study suggest that the wellness of nature and of people can be balanced, if appropriate indicators of ecological health are used to guide green space design.

3.3 Wellbeing benefits are most sensitive to variations in vegetation cover, structural heterogeneity, and naturalness

Objective 4. Investigate whether there is a causal relationship between biodiversity and wellbeing outcomes.

Early on in this thesis, I highlighted the lack of experimental research examining the relationship between biodiversity and human wellbeing benefits, of which there has been only one previous study, Johansson et al.'s (2014) examination of brain activity. In Chapter 5, I discussed the importance of examining wellbeing benefits that the public knows they are deriving, however, the present research appears to be the first experimental study to examine the effects of biodiversity on subjective or self-reported wellbeing. The final phase of my research sought to address this research gap using an Immersive Virtual Environment (IVE) experiment, which is reported in Chapter 6.

Given financial and human resource constraints, I first developed an innovative IVE version of Kirschbaum and colleague's (1993) Trier Social Stress Test (TSST-IVE), which was effective at inducing psychological and physiological stress in participants. The TSST is the gold standard in laboratory-based stress inducement protocols, and thus the TSST-IVE is a useful resource for researchers in this field, and its simplicity of use

may encourage further experimental research. Given the complexity of the relationship between people and nature, and the inherent difficulty researchers face in isolating targeted attributes or experiences, greater uptake of experimental research is required.

4.1 The TSST-IVE is a cost-effective and resource efficient adaptation of the gold standard protocol for inducing stress, and could be used in future experimental research

Consistent with evolutionary theories, the low biodiversity environment – portraying the least structural variation, the lowest number of bird species sounds, and the fewest natural scents – elicited the greatest recovery from stress. Once again, as with the comparative study in Chapter 5, the relationship between biodiversity and wellbeing benefits was not linear. The moderate biodiversity IVE elicited the least effective recovery of the natural environments, and at times was even less restorative than the urban environment. Great care was put into systematically selecting the environments depicted in the IVEs, and as such, interpreting this finding was not straightforward (nor easy to swallow). However, as there were no significant differences in the characteristics of the participants in each group (e.g. nature connectedness, environmental knowledge) this suggested the finding may have been caused by an extraneous variable present in the IVE itself. I posited this variable was the noticeably brighter green of the vegetation in the moderate biodiversity environment, which may have been perceived by the highly educated participants in my experiment to be the presence of invasive plant species. Color, particularly in natural environments, is inherently difficult to quantify, because "colour is relative" (Mbina and Edem, 2015, p. 85) and "issues of plant age, light and sun angles, adjacent colours, and leaf thickness, texture and surface coatings being considerations for plant colour – all reasons for science to be cautious of colour as an aspect of conservation" (Grose, 2012, p. 160). Clearly, any exploration of color in the context of nature and wellbeing will add further complexity to an already complex relationship. Nevertheless, color may be one of the visual cues that inform people about the health and diversity of the natural environment (Grose, 2012), and despite its complexity it should be explored further. As Mbina and Edem

4.2 Low biodiversity facilitated the most effective stress recovery; moderate biodiversity facilitated the least effective stress recovery

4.3 Environment color has received little research attention in the nature and wellbeing domain, and color may be a rapid indicator of ecological quality for laypeople

(2015, p. 81) profess, “none of the visual elements gives us so much pleasure as colour” – perhaps no visual element gives us as much rapid information about the state of our environment, either. We easily use color to assess the health of things in everyday life, such as our food (e.g. we will inspect the color of meat and vegetables prior to eating them) and our skin (e.g. redness, bruising may indicate some lack of wellness). However, to date, the only research examining the relationship between wellbeing and color in nature, appears to have been in the green exercise domain, where researchers compared mood responses after participants exercised whilst watching a video of either a green natural environment, a gray-scale (achromatic) version of the same scene, or a bright red (filtered) version (Akers et al., 2012). The green exercise study demonstrated some positive effects of environment color on mood, however, the color differences between scenes were stark and artificial (e.g. red grass and trees), and would never occur in the real world. Future research could explore the effects of color on perceptions of ecological quality, place attachment, and the attainment of wellbeing benefits in nature. Virtual environments provide an avenue through which these variables can be manipulated or controlled for. Further, IVEs may be recorded in familiar environments with which participants have an emotional connection, and the attributes of that place can be modified to understand the effects of attachment on people’s perceptions. Virtual reality (VR) technology can be mobile, and thus, can be used *in situ* to examine park users’ perceptions of environmental change in familiar environments.

The IVE experiment in Chapter 6 also demonstrated the effects of multi-sensory stimulation on experiences of nature, which has only been superficially explored in the nature and wellbeing domain to date. The present study appears to be the first to include three different stimuli to provide for a truly multi-sensory experience (for a review of sensory nature research see Franco et al. (2017)). Separately, research into the benefits of nature sounds (e.g. Medvedev et al., 2015) and scents (Weber and Heuberger, 2008) is growing, but they have not been examined concurrently. Annerstedt et al. (2013) found that experiencing a VR forest without sound may evoke feelings of fear or discomfort that limit psychological restoration. Similarly, relaxation in the multi-sensory IVE in the present study was greater than in the visual-only IVE, however, the most interesting finding is that participants who were not provided with a multi-sensory

experience perceived the quality of the environment differently (e.g. it was perceived to contain a much higher number of weeds and to be richer in plants species). It was not perceived to be any less rich in animal species, despite containing no animals, highlighting the weight human beings place on our visual sense. Research examining the contribution of non-visual aspects of the environment to our perception of ecological attributes appears to be limited, however, the influence of sound on landscape preferences has been explored (e.g. Carles et al., 1999). Whilst engaging multiple senses may result in improved wellbeing outcomes for people, it might also distract visitors from careful observation of the environment unless they are prompted to focus their attention, perhaps through interpretation. Throughout this thesis, I emphasized the role interpretation might play in improving observational abilities amongst park users, and this finding of enhanced perceptive ability during focused attention gives further support to this. Given the importance placed on the "sounds and smells of nature" in valued places (Chapter 3), the relationship between perceptions, benefits, and sensory stimulation should be explored further, as well as the role interpretation or informal instruction might play in strengthening those relationships.

4.4 A visual-only nature experience, while less restorative than a multi-sensory experience, resulted in greater scrutiny of the environment, for better (greater plant diversity) or worse (more weeds)

Lastly, in Chapter 4, I highlighted the need to understand and control for visitor movements in urban green spaces when studying perceptions of the environment, suggesting that without this, the ability of environmental assessments and isolated park attributes to be perceived by visitors will be limited. This was supported by the IVE experiment, which found that biodiversity perceptions accurately reflected ordinal biodiversity levels when given absolute control over participants' immersion in the environment. As such, it highlights a key limitation of experimental research, i.e. whilst experiments help demonstrate causality between variables, we must acknowledge that many people may not experience these variables the same way *in situ*. I suggested greater effort could be paid to ensuring that biodiversity attributes are distributed throughout urban green spaces, so that they are visible in highly used areas, where they may become familiar to a greater number of people. Nassauer (1995, p. 169) argues

against such a strategy, suggesting this would be "an 'in your face' approach to displaying ecological function [that] would logically extend to exposed septic systems, a landfill in every yard, corporate headquarters sited at chemical dumps, and a sense of ecological justice about natural disasters like flooding and drought. It requires people to accept what they regard as ugly or uncomfortable in exchange for what is attractive and familiar." Similarly, Daniel (2001, p. 267) suggests that a focus on ecological attributes means "neither expert design principles nor human perceptions and preferences are deemed relevant" and Parsons and Daniel (2002, p. 54) further question the need to "accommodate" an ecological aesthetic in their defense of scenic environments.

In light of my research findings, I consider these to be alarmist views, which exaggerate the lesser preference exhibited toward ecologically rich environments in landscape preference studies. Throughout my PhD, natural environments were invariably restorative and perceived favorably by the public. In the IVE experiment, there was no significant difference in perceived aesthetic beauty between natural environments differing in structural heterogeneity, despite some differences in restorativeness and perceptions of ecological attributes.

We can continue, as we have for two hundred years, to design and manage Australian urban parks based on European ideals, knowing full well that such landscapes are unsustainable in the Australian landscape (Pitman, 2010) and provide little habitat to native species. We can continue with current management practices, knowing that urban people are becoming increasingly disconnected from the natural processes that sustain their lives, lament their lack of ecological knowledge, and continue on our trajectory of environmental generational amnesia. Or, we can use urban nature to begin rewriting this story. Acknowledging that people are drawn to relatively depauperate environments of low structural complexity need not be considered a lost cause for conservation; such environments can be used to attract visitors who might not *yet* have a preference for complex environments. Whilst preferences are relative (i.e. one prefers this landscape to that), perception is everything, it is the entirety of our processing, interpretation, and experience of the world, and cannot be ignored. Introducing elements that are perceived as being indicative of ecological quality whilst

4.5 We can use urban green space to begin rewriting the story of "people" and "nature" and start unwinding our collective environmental generational amnesia

still being considered attractive or safe (e.g. perhaps future research will reveal color diversity as an avenue to achieve this) may pique the public's observational abilities and encourage familiar urban environments to evoke continued feelings of fascination and escape over time.

7.3. Conclusion of findings related to research objectives

This PhD was not a study of place attachment, and it was never intended to be so. However, the results that emerged from this research, when examined in the context of past studies, appear to tell a story in which place connections play a central role.

In natural environments that one has an emotional connection with, the ecological attributes of nature – those that are indicative of an environment's health – are of great importance. They are highly valued by individuals, noticed, remembered, and thought to contribute to an individual's restorative outcomes. In everyday natural environments, or those that are less familiar or less valued, one has limited ability – or perhaps care – to perceive ecological attributes such as biodiversity, regardless of education level, environmental knowledge, or nature relatedness – all personal characteristics we might reasonably expect to influence the way people perceive the natural world. At a whole-park level, simple measures of biodiversity indicators do not accurately reflect people's perceptions of park attributes, suggesting a need to examine the ways people move through urban parks, and controlling for such movements when studying perceptions and responses to nature. From a practical standpoint, the results suggest a need to acknowledge these movements during the planning and management of resource distribution throughout green spaces to encourage exploration of areas with higher biodiversity. With absolute control over people's immersion in, or exposure to natural environments, simple measures of biodiversity attributes such as structural heterogeneity accurately reflect biodiversity perceptions, suggesting certain visual cues do influence the public's perceptions and can be used to maximize biodiversity

experiences around popular areas such as carparks and commuting routes, where people are most likely to be exposed to them. Subtle increases in ecological complexity need not be considered aesthetically displeasing, and may substantially contribute to the ability of familiar natural environments to engage visitors' innate curiosity and fascination about the natural world, and ultimately, improve wellbeing outcomes. In any case, we can no longer continue to prioritize human aesthetic preferences or wellbeing over the health of the environment, and the findings presented in this thesis suggest there is clear potential to create a more sustainable future where biodiversity is conceived and managed as equally important.

The findings of this research have led me to question a recently published conceptual framework outlining the links between biodiversity, human wellbeing, and perceptions of biodiversity (Pett et al., 2016), shown in Figure 7.1. The unidirectional nature of the posited relationship between wellbeing and perceptions of biodiversity is not supported by the findings of my research. Rather, perceptions of biodiversity influence wellbeing outcomes, more strongly than actual biodiversity attributes. Furthermore, the link between biodiversity perceptions and pro-biodiversity behavior is unlikely to be direct. As suggested in this thesis, perceptions of biodiversity attributes may influence the development of emotional attachments to place over time. Research suggests that these attachments may lead to place-protective actions, which in turn would protect biodiversity *if* it has become a valued attribute of the loved environment. In Figure 7.2, I propose a simple conceptual framework that demonstrates the potential links between perception, attachment, and wellbeing, based on the findings and connections identified in this thesis. At each step in the framework, there is potential for interventions that encourage contact with nature (e.g. as a form of upstream health promotion (Maller et al., 2006)), or increase observational or perceptive abilities (e.g. interpretation, and techniques such as aiming to discover "Three Good Things" in nature as suggested by Richardson and Sheffield (2017)) – each of which may work to increase the value and concern people feel for biodiverse environments.

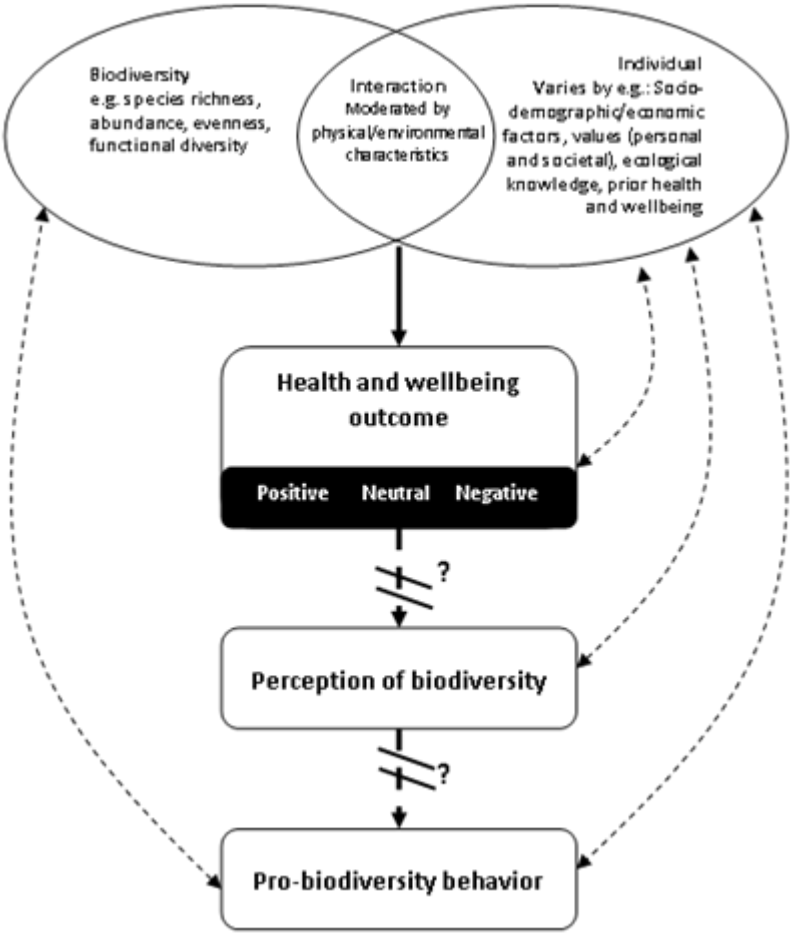


Figure 7.1. Conceptual framework of human-biodiversity interactions and outcomes for health and wellbeing, perceptions of biodiversity and pro-biodiversity behaviour,

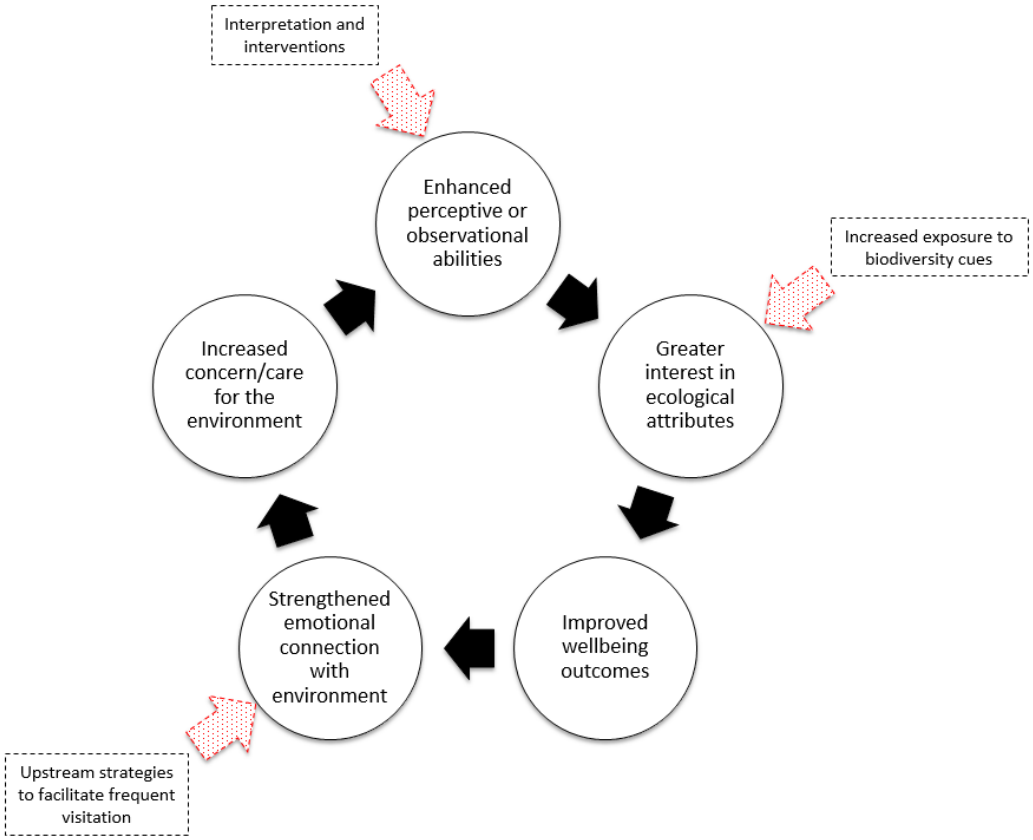


Figure 7.2. Proposed conceptual framework illustrating the potential role of biodiversity in improving wellbeing and concern for biodiverse environments. Colored arrows indicate opportunities for influencing outcomes.

7.4. Recommendations

Overall, the findings of this thesis support the view that ecological values and human wellbeing can be balanced in urban areas, and suggest that striving to achieve such a balance will likely result in additional benefits such as strengthening emotional connections between individuals and natural places. Seven recommendations for urban planning and park management are provided, which offer potential avenues through which these outcomes may be achieved.

7.4.1. Set targets for increasing complexity in planar attributes such as vegetation cover and habitat diversity in urban parks.

Focusing management attention on attributes that are traversed across or beneath may provide the best avenue for ensuring that concerted efforts to increase biodiversity can be perceived by visitors. The recently updated 30-Year Plan for Greater Adelaide (DPTI 2017) provides a clear mandate for Councils in South Australian to do so, with biodiversity being one of 14 core "policy themes" for the State Government, and its key target being canopy cover. However, the focus of the strategy is on increasing canopy cover only in council areas with less than 30% tree cover, which does not include the three council areas included in this study. Clearly, a council-wide canopy target does not go far enough to ensure that perceptions of biodiversity are high in parks. This study did not examine perceptions of biodiversity along roadsides and streets verges, but it is unlikely that biodiversity perceptions in these spaces will be as high as in parks and gardens (but is worthy of further exploration). Given the value placed on formal green space by the public, and the unique benefits they facilitate, separate targets should be set for canopy cover in streetscapes and parks. Significant improvements in wellbeing were reported in parks containing closer to 60% vegetation cover, and although this will not

be possible in all types of parks (e.g. sports fields), coverage can be surprisingly high when effort is put into planting around the perimeter of open space. For example, Newland Park (Figure 7.3) contains close to 30% vegetation cover despite being a baseball field, and could accommodate further increases without impacting on the primary function of the site.

Highly effective schemes such as the SA Urban Forest Million Trees Program – which facilitated the growing and planting of trees by communities throughout urban SA – was discontinued after planting targets were met in 2014. Such a program could be reinstated to reach new targets that are tailored specifically to urban parks.



Figure 7.3. Newland Park, Burnside Council.

7.4.2. Planners should not overlook the importance of nature parks, because these environments were valued more than any other type of green space in this study (Chapter 3).

Whilst nature parks commonly exist outside of urban areas, Adelaide is fortunate to have large conservation areas and National Parks on the urban periphery, e.g. Belair National Park. Councils should look for ways to encourage their constituents to access these sites, for example through connector trails and linear parks that link popular urban parks to larger natural areas. As different types of parks provide different benefits (e.g. as shown in Chapter 5) promoting greater use of multiple park types may enable planners to cultivate public appreciation of different natural attributes, including biodiversity, by using urban parks as gateways for exploration and learning.

Furthermore, we must ensure that these favored places – our nature parks – are safeguarded against encroachments, for example as a result of urban sprawl, which is of greatest relevance to larger councils such as Burnside and Mitcham, which stretch into the peri-urban "hills" areas of metropolitan Adelaide. Preventing this encroachment will be aided by State planning guidelines, which seek to limit 85% of future development to existing urban areas (DPTI 2017), however, the resulting infill development that will take place to meet population growth will increase housing densities and likely see a reduction in the size of backyards and private green spaces. Thus, greater pressure will be placed on Councils to ensure that public green spaces are an enriching source of nature contact for urban inhabitants.

7.4.3. Design parks so that they facilitate fascination, e.g. by skirting trails through different habitats/ecosystems, and encouraging exploration of the broader park.

The results of this study suggest that urban park users might not explore green spaces to their full extent. Whilst my first recommendation suggests habitat diversity should be increased, this may not be sufficient to influence the public's perceptions of biodiversity unless they are encouraged to travel through or past these habitats. Thus, urban parks should be designed in such a way that they invite exploration, e.g. through the use of trails that wind through visually distinct habitat types. Certain urban parks, such as sports ovals, often contain no trails at all (e.g. Figure 7.3). A trail winding through the canopied and open areas around the perimeter of the park in Figure 3, however, could encourage greater exploration of the environment whilst not interfering with its primary function. Such an action, however, should be coupled with the previously recommended increase in diversity, so as to ensure the public's exploration is a rewarding experience. Whilst the management of large protected areas might employ the notion of "sacrificial management" where park managers plan for the majority of use to occur in smaller, concentrated areas of parks to reduce impacts on the surrounding environment, such an approach should not be employed in urban areas. As discussed previously, the signs of human impacts in urban parks will generally be considered acceptable to visitors, and the public should feel welcome to explore parks in their entirety. Furthermore, biodiversity perceptions were not affected by the presence of anthropic elements such as recreational facilities and play equipment in Chapter 4. Thus, anthropic elements could be used to encourage broader exploration of parks, e.g. visitors could be encouraged to walk through various habitats on their way to drawcard facilities such as playgrounds and picnic areas. Managing urban parks to improve biodiversity does not require that park managers negate anthropic element diversity, as this study showed there is great potential to increase ecological attributes in urban parks without compromising the ability of green space to perform existing functions, i.e. recreation facilities need not

detract from nature experiences, and ecological attributes need not detract from aesthetic preferences or recreational activities.

7.4.4. Use savanna-like areas to attract visitors, but plan for park experiences to take people into the more highly vegetated areas of parks.

In this study, vegetation cover was the strongest visual cue influencing respondents' perceptions of biodiversity, however, restorative benefits may be greater in lower biodiversity, savanna-like settings, and past research shows that these environments are attractive to people. Thus, urban parks must still contain traditional "parkland" areas that are familiar, attractive, and restorative to the public, although greater attention should be given to using native rather than exotic grasses. At the same time, parks should incorporate areas with much higher levels of vegetation, and as per the previous recommendation, visitors should be encouraged to also experience these areas of parks. It is in these highly vegetated areas, which are perceived as having higher biodiversity, that there lies an opportunity to quietly educate visitors about the importance of biodiversity and allow them to engage in mindful observation of the natural environment. Providing well-formed trails and signage could also be important in encouraging use, a feeling of safety, and sense of exploration. As small changes in park naturalness, habitat diversity, and vegetation cover had a dramatic effect on predicted biodiversity perceptions, it is suggested that (a) greater exploration away from the savanna-like parts of urban parks into those that are more natural or diverse, will result in substantially higher perceptions of biodiversity; and (b) care should be taken to ensure that any management changes seek to enhance, rather than impact or detract from these attributes.

7.4.5. Make use of interpretive techniques that encourage visitors to take notice of important ecological attributes and concepts such as biodiversity in urban parks.

When vegetation cover was controlled for, a one-point increase in perceived biodiversity was associated with a 36% increase in stress improvement, suggesting that although visual attributes are important, the wellbeing benefits they facilitate could be maximized by ensuring the public's perception of them matches the values they exhibit. Interpretation offers a clear means of achieving this, and although its use is frequently employed in protected areas, its presence in urban parks is far less common. Interpretation need not be costly or resource-intensive, and could be introduced in conjunction with community efforts to increase diversity in parks, e.g. through a renewed Urban Forest Program. Even simple labels have been shown to change the way people perceive natural environments (Hodgson and Thayer, 1980), and these could be implemented quite easily. In Chapter 5, I suggested that a concerted effort to encourage people to observe ecological attributes, dynamic features, and micro-variables in urban parks might help them to develop an appreciation for those attributes over time, and an awareness of their absence in depauperate environments.

Furthermore, management agencies (e.g. local, state or federal government) should consider creating roles for urban rangers. Urban rangers could implement interpretive programs, engage the public, and communicate the importance of particular natural attributes to them, as is commonly done in large protected areas. Whilst the parks in urban areas are far smaller, they are visited by large numbers of people more frequently. Due to their closer proximity to city schools, they also offer excellent potential as hubs for longer term environmental education programs aimed at building the next generation of biodiversity stewards. From an efficiency perspective, the potential to influence public perceptions of nature is likely greater in urban areas than in wilderness areas, due

to the great diversity of people with easy access to urban parks – a visitor base that unlike wilderness users, may not have strong existing nature values.

7.4.6. Don't under-estimate the value a small park can play in nurturing an appreciation of biodiversity.

In this study, park size was not related to the public's perceptions of biodiversity, suggesting an opportunity for small parks to provide "pockets" of biodiversity experiences in urban neighborhoods. Whilst these small parks will never sustain the high levels of species richness that large natural areas are able to, if they are *perceived* as biodiverse, they are serving an important purpose. Furthermore, very small parks generally only provide for passive recreation (e.g. sitting, relaxing), so significantly increasing their vegetation cover could inject biodiversity experiences into established urban areas without detracting from the passive recreation experiences these sites facilitate.

7.4.7. Create a planting scheme that showcases biodiversity rather than one that is driven by a desire for hardiness.

Earlier, I discussed the ways in which the management of urban parks – in an effort to be robust to high levels of human use – may inadvertently create sterile experiences and miss opportunities to connect people with the importance of biodiversity and the consequences of its loss. Being unable to see changes to the natural environment as direct consequence of one's use of it, does not serve biodiversity conservation in areas inside or outside of the urban boundary. Learning to see how people's use of nature affects its quality may result in greater care or concern for the use of more vulnerable or valuable natural areas such as National Parks (e.g. by sticking to defined trails in protected areas). Without having experienced this is familiar settings, we cannot expect urban people to suddenly notice and comprehend human impacts in less familiar and less-frequented natural areas. Whilst resilient (yet exotic) species and homogeneous

habitats likely have an important place in urban green space (e.g. sports fields), they should be used only where the cons outweigh the pros of incorporating native species and greater diversity. As Lindemann-Matthies (2008) demonstrated, responses to native grasslands can be quite positive, regardless of the small scale they are implemented at, and as such, people should be given opportunities to experience, use, and impact such environments in urban areas (where human impacts are a foregone conclusion, anyway). Certainly programs for priority erosion control may need to be introduced and these have an associated cost, but the long term value of exposing people to more biodiverse environments far outweighs short term costs.

7.5. Future research

This section outlines eleven areas for future research, which are informed by the limitations and main findings of this study. These areas are:

7.5.1. Consider the relationship between place attachment and the development of improved perceptive abilities amongst park visitors.

In this study, and as demonstrated by Figure 7.2, I posited that being encouraged to take notice of natural attributes and sensory stimuli in parks may facilitate the development of an emotional connection, or care, for those places, and thus an improved ability to perceive when the environment is under pressure. Future research could examine this relationship by comparing the perceptive or observational abilities of respondents differing in their level of emotional attachment to a particular place. The converse could also be tested, i.e. examining whether interventions that promote observation in nature lead to the development of emotional attachments to those places. Richardson et al. (2010) found that encouraging people to take notice of "three good things" in nature each day led to an increase in nature connectedness. The proposed study would build on

such work, by testing whether an emotional connection could be made with particular places, and would require a longitudinal or before-and-after intervention study.

7.5.2. Examine the influence of nature-derived wellbeing benefits on pro-environmental behaviour.

Li (2011) suggests that directly experiencing events that one perceives to be related to environmental problems such as climate change, can increase concern and action in regards to that problem. In this thesis, I posited that greater awareness of, and direct experiences of positive environmental conditions (such as biodiversity) might also encourage positive environmental behaviors. Thompson (2012) suggests that the public prefers to discuss the benefits of nature, rather than the impacts humans have on it, suggesting there is potential for such an avenue to lead to actions that enhance or protect biodiversity. Furthermore, studies have shown that nature-connectedness may be associated with participating in pro-environmental behaviors (e.g. Geng 2015), and emotional attachments to certain places can encourage people to engage in place-protective actions (e.g. Stedman 2002).

7.5.3. Further investigate the reliability of the TSST-IVE and its effectiveness in inducing stress in a broader range of wellbeing measures.

The TSST-IVE was effective at inducing psychological and physiological stress in this study. The traditional TSST was initially shown to increase salivary cortisol, a frequently used biomarker of psychological stress (Kirschbaum 1993). If the TSST-IVE were to be more widely adopted, it should be tested against a range of wellbeing measures, including multiple-response mood scales (e.g. Profile of Mood States, or the Positive Affect/Negative Affect Scale), the Perceived Restorativeness Scale, and additional physiological measures of stress, such as salivary cortisol, blood pressure,

and Electrodermal activity (the latter was included in the present study, but did not result in sufficient usable data).

7.5.4. Further explore the types of attributes and doses required to facilitate a range of wellbeing benefits, and explore the idea of "micro" nature doses using IVE.

Future research could examine whether nature "doses" (i.e. time needed in nature to derive benefits) differs between natural environments exhibiting different attributes. Shanahan et al. (2016) suggest that people who visit green space for at least 30 minutes each week are less likely to have depression or high blood pressure, setting a clear benchmark that health practitioners should encourage the public to meet. However, only 15% of Australian adults (aged 18-64) are thought to meet national Physical Activity Guidelines (ABS 2018) despite the prevalence of media attention given to physical health and inactivity, so it is unlikely that health-based recommendations of "doses" for nature contact (i.e. midstream approaches to improving public health) will substantially change the frequency or duration with which urban populations interact with nature. Rather, we should examine the most common experiences of nature in cities – perhaps cumulative "micro" doses of much shorter durations could have great benefit, especially if we look at ways we can enhance those experiences to improve outcomes for human health and nature simultaneously (i.e. upstream approaches championed by Maller et al. (2006) and Townsend and Weerasuriya (2010)). There is some suggestion that these small doses of nature could be quite effective (e.g. based on the stress recovery seen in Chapter 6, and a study by Cracknell et al. (2016) that showed improvements to heart rate and blood pressure did not further improve after five minutes of watching an aquarium). In exploring micro-doses of nature, IVE technology will be incredibly useful, and could be used to simulate the most common types of nature contact in cities (e.g. driving past green space). The application of virtual reality is in its infancy in terms of nature and wellbeing research, but it has great potential for examining the effects of a wide range of nature attributes on human wellbeing and perception.

7.5.5. Further development of the UNPI, including measures of vegetation cover, is warranted.

Future research should look at improving the Urban Park Naturalness Index and combining it with measures of vegetation cover into a single tool. Furthermore, the finding that planar elements are the most perceptible to the public, suggests there is potential for the development of a remote UPNI tool (perhaps an additional function of iTree Canopy) to be used in estimating perceived biodiversity in urban parks, without the need for on-site assessments. The repeated finding in past research that "exotic" vegetation may be more attractive or more recognizable to the public (Qiu et al., 2013, Hoyle et al., 2017) should be explored further. While I recommend expanding the UPNI, it is also worth testing the public's ability to perceive its individual components, such as the nativeness of species in the environment. In Chapter 3, native species were a loved attribute of many favorite places, however, "plants and trees" in general were some of the most frequently reported loved attributes, and we cannot assume that these statements referred to native species.

7.5.6. Improve our understanding of how perceptions of biodiversity influence visitors' benefits or values.

Pett et al. (2016) posited that the attainment of wellbeing benefits may influence perceptions of biodiversity (Figure 7.1). Whilst I found the converse, that perceptions of biodiversity influenced the wellbeing benefits participants derived (Chapter 5), the relationship posited by Pett and colleagues should also be examined. It is likely that such a relationship would be moderated by improvements in perceptive abilities or understanding of biodiversity.

7.5.7. Explore the role of place attachment by comparing the benefits people attain in an environment they are familiar with, to an unfamiliar environment with similar levels of biodiversity.

Earlier, I questioned whether Fuller et al.'s (2007) results may have been influenced by respondents' emotional attachments to the green spaces included in the study, rather than biodiversity, due to the measures of wellbeing that were included. In my experimental study, participants did not have emotional attachments to the environments I included, so I could not directly test the effects of place attachment on benefit attainment in biodiverse environments. Future studies could explore this topic by comparing wellbeing improvements in the same participants in two equally biodiverse environments: (a) an environment that participants are familiar with and emotionally attached to, and (b) an unfamiliar environment that they hold no preconceived ideas about.

7.5.8. Compare strategies designed to either: (a) strengthen perceptive abilities related to biodiversity, or (b) increase understanding of biodiversity, in terms of their effectiveness in improving the wellbeing benefits people derive from natural environments.

Whilst a substantial education intervention (i.e. several weeks of lessons) has been shown to improve the number of species that people can identify (Lindemann-Matthies 2002), the effectiveness of shorter interventions (e.g. brochures, signs, talks about the importance of biodiversity) on perceptive abilities does not appear to have been examined. Future studies should compare the effectiveness of this knowledge-based approach to one that simply targets observational activities (this may be workshops with

a dendrologist or could be through the use of unfamiliar objects that people have no pre-conceived ideas about, such as a piece of artwork, as discussed in Chapter 6). Furthermore, there has been little exploration of engaging the perceptive abilities of our non-visual senses, and interpretive opportunities could focus on encouraging greater attention to the sounds, smells, and textures of nature.

7.5.9. Examine the influence of color on perceptions of ecological quality and biodiversity.

As discussed by Grose (2012), color in conservation has been largely unexplored. However, the field of "color psychology" has examined the wellbeing and behavioral effects of color in objects, food, and advertising for decades. Color psychology may have an important role to play in bridging conservation, human perception, and wellbeing benefits in nature. Given the difficulties associated with quantifying the colors of nature (as discussed earlier), examining the role of color on people's perceptions of ecological quality will likely require the use of manipulated imagery (e.g. artificially changing hue in scenes, or systematically including/excluding plants exhibiting particular colors). Such an exploration would benefit from using IVE technology. Furthermore, it is possible that the public's attraction to "exotic" plant species is related to color. If plant color is one of the visual cues that influence the ways people perceive the health or quality of the natural environment (and their attraction to it), it is an important avenue for future research in this field.

7.5.10. Further examine the role of different human senses on perceptions of nature and on nature-derived wellbeing benefits.

Although sight is our dominant sense (Colavita, 1974), humans are multi-sensory. Research exploring the wellbeing benefits of nature sounds is becoming much more

prevalent (Alvarsson et al., 2010), however, research into the scents (olfactory sense) and textures (tactile sense) that often contribute to nature experiences is very limited. Research examining the tactile aspects of nature appears to have only explored the benefits of touching animals, and of participating in hands-on activities like gardening (Franco et al., 2017). Whilst researchers have looked at the effects certain scents have on humans (e.g. peppermint oil) (Warm et al., 1991), my study was the first to examine how sound and scent may enhance nature experiences, affect perceptions of nature, and influence nature-derived wellbeing benefits. Further research should examine the relative effects of sound and scent (as well as other senses) on nature experiences, and also their combined effects, as in this study.

7.5.11. Explore the idea of "super-responders" and "non-responders" in terms of wellbeing benefit attainment in nature.

In the studies reported in Chapters 4 and 5 of this thesis, respondents were able to convey their perceptions and wellbeing responses about multiple parks they visited. This may be considered a limitation of the study, as discussed in Chapter 2, however, it also provided interesting insights into the ways a single individual may respond to different environments. For a proportion of my study population, neither objective nor perceived biodiversity or naturalness had any influence on wellbeing responses, for better or worse – some people always derived a very high level of wellbeing benefit, irrespective of natural attributes, and others always derived very little, or no, perceived benefit. It hinted at the existence of potential "super-responders", "dynamic responders" and "non-responders" to nature, in the vein of exercise physiology research that suggests a small proportion of the population may derive very high levels of physiological benefit from small amounts of exercise (super-responders), whilst another proportion will derive little benefit from very high levels of physical activity (non-responders) (Vollaard et al., 2009) and this information is used to tailor exercise regimes to people's physiological makeup. The mechanisms through which subjective wellbeing benefits are derived from nature are likely to be more complex than those of

the physical benefits derived from exercise, so it would seem plausible that there are indeed a variety of different responders to nature. Further exploration of this idea could help us "triage" the approaches required to strengthen the relationship between wellbeing and nature in urban areas. For example, dynamic responders (whose benefits fluctuated with changes in the environment) might benefit best from strategies that seek to improve their perceptive or observational abilities so that they mirror objective measures. Super-responders may require little intervention, and park managers could modify the natural environment to improve biodiversity without impacting on the benefits those people derive – which are always very high. However, if one is a non-responder, research would be required to understand the reasons why one feels they derive no wellbeing benefit from nature experiences. The finding was not related to their perceptions of the environment, so improving observational abilities as with the dynamic responders, will not change their wellbeing outcomes. Perhaps they would benefit most from education on the value of natural environments, or perhaps they need only to spend more time in nature to become tuned in to the effects it has on their wellbeing, or perhaps, as with exercise non-responders, they simply will never attain the levels of benefit from nature that we might hope to see.

7.6. Conclusion: Significance of work

Overall, this thesis is significant for the following reasons. It presents:

- The first controlled trial examining the effects of biodiversity on human stress recovery;
- The first experimental study examining the effects of a tri-sensory immersive experience on the wellbeing benefits derived from nature experiences;
- A novel IVE version of the gold standard in laboratory-based stress inducement protocols – the Trier Social Stress Test;

- A series of rapid park assessment tools that balance efficiency and usability in the objective measurement of ecological attributes in urban parks;
- To date, the largest study examining the wellbeing benefits of biodiversity in urban areas, i.e. it has examined a far greater number of individual sites and collected a far greater number of individual biodiversity perceptions and responses;
- The first Australian study comparing wellbeing benefits and direct measures of biodiversity attributes at a site-scale in urban areas.

In conclusion, the thesis presented here is that balancing the health of nature and the health of people in urban areas is not only possible, but crucial to the cultivation of love and concern for the natural world – which in turn is crucial to the sustainable management of the planet. This study has demonstrated the importance of people's perceptions on the wellbeing benefits they derive from natural environments in urban areas. It has both advanced our understanding of the nuanced relationship between nature and wellbeing, and provided fruitful avenues for future research. Importantly, this study has highlighted the potential for a reciprocal relationship between mindful observation of nature and the development of emotional connections to places, and has suggested opportunities through which park managers and planners can take advantage of this relationship for the mutual benefit of people and nature. Repeatedly, this study has pointed to the importance of engaging the public's observational abilities in the attainment of wellbeing benefits and their ability to perceive changes to their environment, and the part this may play in closing the psychological gap between biodiversity loss and the lives of urban inhabitants. Perhaps, as poet Mary Oliver declares, "Attention is the beginning of devotion" – and now more than ever, we could all be a little more attentive and devoted to nature.

LITERATURE CITED

ABDEL-KHALEK, A. M. 2006. Measuring happiness with a single-item scale. *Social Behavior and Personality,* 34**,** 139-150.

AERTS, R., HONNAY, O. & 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**,** 5-22.

AKERS, A., BARTON, J., COSSEY, R., GAINSFORD, P., GRIFFIN, M. & MICKLEWRIGHT, D. 2012. Visual color perception in green exercise: positive effects on mood and perceived exertion. *Environ Sci Technol,* 46**,** 8661-6.

ALLEN, A. P., KENNEDY, P. J., DOCKRAY, S., CRYAN, J. F., DINAN, T. G. & CLARKE, G. 2017. The Trier Social Stress Test: Principles and practice. *Neurobiol Stress,* 6**,** 113-126.

ALTMAN, I. & LOW, S. M. 1992. *Place Attachment,* Springer US.

ALVARSSON, J. J., WIENS, S. & NILSSON, M. E. 2010. Stress recovery during exposure to nature sound and environmental noise. *Int J Environ Res Public Health,* 7**,** 1036-46.

ALVES, R. R. & ROSA, I. M. 2007. Biodiversity, traditional medicine and public health: where do they meet? *Journal of Ethnobiology and Ethnomedicine,* 3**,** 14.

ANNERSTEDT, M., JONSSON, P., WALLERGARD, M., JOHANSSON, G., KARLSON, B., GRAHN, P., HANSEN, A. M. & WAHRBORG, P. 2013. Inducing physiological stress recovery with sounds of nature in a virtual reality forest--results from a pilot study. *Physiol Behav,* 118**,** 240-50.

ANNERSTEDT, M., OSTERGREN, P. O., BJORK, J., GRAHN, P., SKARBACK, E. & WAHRBORG, P. 2012. Green qualities in the neighbourhood and mental health - results from a longitudinal cohort study in Southern Sweden. *BMC Public Health,* 12**,** 337.

APLET, G. H. & COLE, D. N. 2010. The Trouble with Naturalness: Rethinking Park and Wilderness Goals. *In:* COLE, D. N. & YUNG, L. (eds.) *Beyond naturalness: Rethinking park and wilderness stewardship in an era of rapid change.* Washington, D. C.: Island Press.

APPLETON, J. 1975. *The experience of landscape,* London, New York, Wiley.

ARRHENIUS, O. 1921. Species and Area. *Journal of Ecology,* 9**,** 95-99.

ASPINALL, P., MAVROS, P., COYNE, R. & ROE, J. 2015. The urban brain: analysing outdoor physical activity with mobile EEG. *Br J Sports Med,* 49**,** 272-6.

ATKINSON, S. 2011. Moves to measure wellbeing must support a social model of health. *BMJ,* 343.

AUSTRALIAN BUREAU OF STATISTICS 2004. Environmental Issues: People's Views and Practices. Canberra.

AUSTRALIAN BUREAU OF STATISTICS 2007. National Survey of Mental Health and Wellbeing: Summary of Results. Canberra.

AUSTRALIAN BUREAU OF STATISTICS 2011. Australian Social Trends March 2011: Health Outside Major Cities. *In:* STATISTICS, A. B. O. (ed.). Canberra.

AUSTRALIAN BUREAU OF STATISTICS 2013. Measure's of Australia's Progress: Appreciating the Environment. Canberra.

AUSTRALIAN BUREAU OF STATISTICS 2015. Australian Demographic Statistics, September 2015. *In:* STATISTICS, A. B. O. (ed.). Canberra.

AUSTRALIAN BUREAU OF STATISTICS 2017a. 2016 Census QuickStats: Burnside. 2017 ed.

AUSTRALIAN BUREAU OF STATISTICS 2017b. 2016 Census QuickStats: Mitcham. 2017 ed.

AUSTRALIAN BUREAU OF STATISTICS 2017c. 2016 Census QuickStats: Unley. 2017 ed.

AUSTRALIAN BUREAU OF STATISTICS 2017d. Data by Region, 2011-16. *In:* STATISTICS, A. B. O. (ed.). Canberra.

AUSTRALIAN BUREAU OF STATISTICS 2018. National Health Survey: First Results, 2017-18. Canberra.

BALLING, J. D. & FALK, J. H. 1982. Development of Visual Preference for Natural Environments. *Environment and Behavior,* 14**,** 5-28.

BALMFORD, A., CLEGG, L., COULSON, T. & TAYLOR, J. 2002. Why Conservationists Should Heed Pokémon. *Science,* 295**,** 2367-2367.

BARTON, J., HINE, R. & PRETTY, J. 2009. The health benefits of walking in greenspaces of high natural and heritage value. *Journal of Integrative Environmental Sciences,* 6**,** 261-278.

BARTON, J. & PRETTY, J. 2010. What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Environ. Sci. Technol.,* 44**,** 3947-3955.

BAUM, A. & POSLUSZNY, D. M. 1999. Health psychology: mapping biobehavioral contributions to health and illness. *Annu Rev Psychol,* 50**,** 137-63.

BEDIMO-RUNG, A. L., GUSTAT, J., TOMPKINS, B. J., RICE, J. & THOMSON, J. 2006. Development of a Direct Observation Instrument to Measure Environmental Characteristics of Parks for Physical Activity. *Journal of Physical Activity and Health,* 3**,** S176-S189.

BEIL, K. & HANES, D. 2013. The influence of urban natural and built environments on physiological and psychological measures of stress--a pilot study. *Int J Environ Res Public Health,* 10**,** 1250-67.

BERMAN, M. G., JONIDES, J. & KAPLAN, S. 2008. The cognitive benefits of interacting with nature. *Psychol Sci,* 19**,** 1207-12.

BERTO, R., BARONI, M. R., ZAINAGHI, A. & BETTELLA, S. 2010. An exploratory study of the effect of high and low fascination environments on attentional fatigue. *Journal of Environmental Psychology,* 30**,** 494-500.

BEUKEBOOM, C. J., LANGEVELD, D. & TANJA-DIJKSTRA, K. 2012. Stress-reducing effects of real and artificial nature in a hospital waiting room. *J Altern Complement Med,* 18**,** 329-33.

BEYER, K. M., KALTENBACH, A., SZABO, A., BOGAR, S., NIETO, F. J. & MALECKI, K. M. 2014. Exposure to neighborhood green space and mental health: evidence from the survey of the health of Wisconsin. *Int J Environ Res Public Health,* 11**,** 3453-72.

BIRD, W. 2007. Natural thinking: Investigating the links between the natural environment, biodiversity and mental health. *Royal Society for the Protection of Birds*.

BIRD, W. 2010. *Foreword in: Innovative Approaches to Researching Landscape and Health: Open Space: People Space 2,* Taylor & Francis.

BODIN, M. & HARTIG, T. 2003. Does the outdoor environment matter for psychological restoration gained through running? *Psychology of Sport and Exercise,* 4**,** 141-153.

BONNES, M., UZZELL, D., CARRUS, G. & KELAY, T. 2007. Inhabitants' and Experts' Assessments of Environmental Quality for Urban Sustainability. *Journal of Social Issues,* 63**,** 59-78.

BORD, R. J., O'CONNOR, R. E. & FISHER, A. 2000. In what sense does the public need to understand global climate change? *Public Understanding of Science,* 9**,** 205-218.

BOWERMAN, B. L. & O'CONNELL, R. T. 1990. *Linear Statistical Models: An Applied Approach,* Duxbury Press.

BRATMAN, G. N., HAMILTON, J. P. & DAILY, G. C. 2012. The impacts of nature experience on human cognitive function and mental health. *Ann N Y Acad Sci,* 1249**,** 118-36.

BRATMAN, G. N., HAMILTON, J. P., HAHN, K. S., DAILY, G. C. & GROSS, J. J. 2015. Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proc Natl Acad Sci U S A,* 112**,** 8567-72.

BRAVERMAN, I. M. 2011. To see or not to see: How visual training can improve observational skills. *Clinics in Dermatology,* 29**,** 343-346.

BROOMHALL, M. H., GILES-CORTI, B. & LANGE, A. 1996. Quality of Public Open Space Tool (POST). Perth, Western Australia: School of Population Health, The University of Western Australia.

BROWN, G., SCHEBELLA, M. F. & WEBER, D. 2014. Using participatory GIS to measure physical activity and urban park benefits. *Landscape and Urban Planning,* 121**,** 34-44.

BROWN, G. & WEBER, D. 2011. Public Participation GIS: A new method for national park planning. *Landscape and Urban Planning,* 102**,** 1-15.

BROWN, P. J., DRIVER, B. L. & MCCONNELL, C. 1978. The Opportunity Spectrum -- Concept and Behavioral Information in Outdoor Recreation Resource Supply Inventories: Background and Application. *Forest Management Faculty Publications.* University of Montana.

BUIJS, A., FISCHER, A., RINK, D. & YOUNG, J. 2008. Looking beyond superficial knowledge gaps: Understanding public representations of biodiversity. *International Journal of Biodiversity Science, Ecosystems Services & Management,* 4**,** 65-80.

CANTWELL, B., CLIFTON, K., DICKSON, L., GERLACH, J., IMAMURA, H., MEDEK, D., O'LEARY COUNAHAN, D. & SANSONI, E. 2012. Comparing the frequency of GP mental health diagnoses between rural and urban communities. *Medical Student Journal of Australia,* 4.

CAPALDI, C. A., PASSMORE, H.-A., NISBET, E. K., ZELENSKI, J. M. & DOPKO, R. L. 2015. Flourishing in nature: A review of the benefits of connecting with nature and its application as a wellbeing intervention. *International Journal of Wellbeing,* 5.

CARDINALE, B. J., DUFFY, J. E., GONZALEZ, A., HOOPER, D. U., PERRINGS, C., VENAIL, P., NARWANI, A., MACE, G. M., TILMAN, D., WARDLE, D. A., KINZIG, A. P., DAILY, G. C., LOREAU, M., GRACE, J. B., LARIGAUDERIE, A., SRIVASTAVA, D. S. & NAEEM, S. 2012. Biodiversity loss and its impact on humanity. *Nature,* 486**,** 59.

CARLES, J. L., BARRIO, I. L. & DE LUCIO, J. V. 1999. Sound influence on landscape values. *Landscape and Urban Planning,* 43**,** 191-200.

CARRUS, G., SCOPELLITI, M., LAFORTEZZA, R., COLANGELO, G., FERRINI, F., SALBITANO, F., AGRIMI, M., PORTOGHESI, L., SEMENZATO, P. & 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**,** 221-228.

CHANG, K., SULLIVAN, W., LIN, Y.-H., SU, W. & CHANG, C.-Y. 2016. The Effect of Biodiversity on Green Space Users' Wellbeing—An Empirical Investigation Using Physiological Evidence. *Sustainability,* 8**,** 1049.

CHIVIAN, E. & BERNSTEIN, A. 2010. *How Our Health Depends on Biodiversity,* Center for Health and the Global Environment, Harvard Medical School.

CINCOTTA, R. P., WISNEWSKI, J. & ENGELMAN, R. 2000. Human population in the biodiversity hotspots. *Nature,* 404**,** 990.

CLARK, N. E., LOVELL, R., WHEELER, B. W., HIGGINS, S. L., DEPLEDGE, M. H. & NORRIS, K. 2014. Biodiversity, cultural pathways, and human health: a framework. *Trends in Ecology & Evolution,* 29**,** 198-204.

CLARK, R. & STANKEY, G. 1979. The Recreation Opportunity Spectrum: A Framework for Planning, Management, and Research. *USDA Forest Service General Research Paper PNW-98.*

COHEN, S., KAMARCK, T. & MERMELSTEIN, R. 1994. Perceived stress scale. *Measuring stress: A guide for health and social scientists***,** 235-283.

COLAVITA, F. B. 1974. Human sensory dominance. *Perception & Psychophysics,* 16**,** 409-412.

COLLADO, S., STAATS, H. & SORREL, M. A. 2016. A relational model of perceived restorativeness: Intertwined effects of obligations, familiarity, security and parental supervision. *Journal of Environmental Psychology,* 48**,** 24-32.

COSTANZA, R. & MAGEAU, M. 1999. What is a healthy ecosystem? *Aquatic Ecology,* 33**,** 105-115.

COX, R. L. & UNDERWOOD, E. C. 2011. The Importance of Conserving Biodiversity Outside of Protected Areas in Mediterranean Ecosystems. *PLOS ONE,* 6**,** e14508.

CRA 2015. Adelaide Radio - Survey 1 2015. Australia: Commercial Radio Australia.

CRACKNELL, D., WHITE, M. P., PAHL, S., NICHOLS, W. J. & DEPLEDGE, M. H. 2016. Marine Biota and Psychological Well-Being: A Preliminary Examination of Dose-Response Effects in an Aquarium Setting. *Environ Behav,* 48**,** 1242-1269.

CRANZ, G. & BOLAND, M. 2004. Defining the Sustainable Park: A Fifth Model for Urban Parks. *Landscape Journal,* 23**,** 102-120.

CRESWELL, J. W. 2014. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,* SAGE Publications.

CRIST, E., MORA, C. & ENGELMAN, R. 2017. The interaction of human population, food production, and biodiversity protection. *Science,* 356**,** 260-264.

D.E.H 2007. No Species Loss: A Nature Conservation Strategy for South Australia 2007–2017. Adelaide, South Australia: Department for Environment and Heritage, Government of South Australia.

DALLIMER, M., IRVINE, K. N., SKINNER, A. M. J., DAVIES, Z. G., ROUQUETTE, J. R., MALTBY, L. L., WARREN, P. H., ARMSWORTH, P. R. & GASTON, K. J. 2012. Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness. *Bioscience,* 62**,** 47-55.

DANIEL, T. C. 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning,* 54**,** 267-281.

DAVEY, H. M., BARRATT, A. L., BUTOW, P. N. & DEEKS, J. J. 2007. A one-item question with a Likert or Visual Analog Scale adequately measured current anxiety. *J Clin Epidemiol,* 60**,** 356-60.

DE VOS, J. M., JOPPA, L. N., GITTLEMAN, J. L., STEPHENS, P. R. & PIMM, S. L. 2015. Estimating the normal background rate of species extinction. *Conservation Biology,* 29**,** 452-462.

DE VRIES, S., VERHEIJ, R. A., GROENEWEGEN, P. P. & SPREEUEWENBERG, P. 2003. Natural environments - healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A,* 35**,** 1717-1731.

DEAN, J., VAN DOOREN, K. & WEINSTEIN, P. 2011. Does biodiversity improve mental health in urban settings? *Med Hypotheses,* 76**,** 877-80.

DEARBORN, D. C. & KARK, S. 2010. Motivations for conserving urban biodiversity. *Conserv Biol,* 24**,** 432-40.

DEFRA 2011. Attitudes and Knowledge Relating to Biodiversity and the Natural Environment, 2007-2011. *The Survey of Public Attitudes and Behaviour Towards the Environment.* UK: Deparment for Environment, Food and Rural Affairs,.

DEMARIS, A. 2005. *Regression with Social Data : Modeling continuous and limited response variables,* New Jersey, Willey.

DIETTE, G. B., LECHTZIN, N., HAPONIK, E., DEVROTES, A. & RUBIN, H. R. 2003. Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: a complementary approach to routine analgesia. *Chest,* 123**,** 941-8.

DRIVER, B. L. & BROWN, P. J. The opportunity spectrum concept and behavioral information in outdoor recreation resource supply inventories: A rationale. USDA Forest Service GeneralTechnical Report RM-55, 1978 Fort Collins, CO, Rocky Mountain Forest and Range Experiment Station. Integrated Inventories of Renewable Natural Resources: Proceedings of the Workshop.

DUNN, O. J. 1964. Multiple Comparisons Using Rank Sums. *Technometrics,* 6**,** 241-252.

DUNNING , J., JOHN B. 1997. The Missing Awareness, Part 2: Teaching Students What a Billion People Looks Like. *Conservation Biology,* 11**,** 6-10.

DURES, S. G. & CUMMING, G. S. 2010. The confounding influence of homogenising invasive species in a globally endangered and largely urban biome: Does habitat quality dominate avian biodiversity? *Biological Conservation,* 143**,** 768-777.

ELO, A. L., LEPPANEN, A. & JAHKOLA, A. 2003. Validity of a single-item measure of stress symptoms. *Scand J Work Environ Health,* 29**,** 444-51.

EVANS, G. W. 2003. The built environment and mental health. *J Urban Health,* 80**,** 536-55.

FRANCIS, J., WOOD, L. J., KNUIMAN, M. & GILES-CORTI, B. 2012. Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Soc Sci Med,* 74**,** 1570-7.

FRANCO, L. S., SHANAHAN, D. F. & FULLER, R. A. 2017. A Review of the Benefits of Nature Experiences: More Than Meets the Eye. *International Journal of Environmental Research and Public Health,* 14**,** 864.

FREEMAN, C. 1999. Development of a simple method for site survey and assessment in urban areas. *Landscape and Urban Planning,* 44**,** 1-11.

FREEMAN, C. & BUCK, O. 2003. Development of an ecological mapping methodology for urban areas in New Zealand. *Landscape and Urban Planning,* 63**,** 161-173.

FROMM, E. 1973. *The Anatomy of Human Destructiveness,* Holt, Rinehart and Winston.

FRUMKIN, H. 2003. Healthy places: exploring the evidence. *Am J Public Health,* 93**,** 1451-6.

FULLER, R. A., IRVINE, K. N., DEVINE-WRIGHT, P., WARREN, P. H. & GASTON, K. J. 2007. Psychological benefits of greenspace increase with biodiversity. *Biol Lett,* 3**,** 390-4.

FULLER, S. & ATKINSON, S. 2016. *Wellbeing and Place,* Taylor & Francis.

GASCON, M., TRIGUERO-MAS, M., MARTÍNEZ, D., DADVAND, P., FORNS, J., PLASÈNCIA, A. & 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**,** 4354-4379.

GENOVART, M., TAVECCHIA, G., ENSEÑAT, J. J. & LAIOLO, P. 2013. Holding up a mirror to the society: Children recognize exotic species much more than local ones. *Biological Conservation,* 159**,** 484-489.

GILES-CORTI, B., BROOMHALL, M. H., KNUIMAN, M., COLLINS, C., DOUGLAS, K., NG, K., LANGE, A. & DONOVAN, R. J. 2005. Increasing walking: how important is distance to, attractiveness, and size of public open space? *Am J Prev Med,* 28**,** 169-76.

GOBSTER, P. H. 1994. The Urban Savanna: Reuniting Ecological Preference and Function. *Restoration & Management Notes,* 12**,** 64-71.

GOBSTER, P. H. 1999. An ecological aesthetic for forest landscape management. *Landscape Journal,* 18**,** 54-64.

GOBSTER, P. H. 2001. Visions of nature: conflict and compatibility in urban park restoration. *Landscape and Urban Planning,* 56**,** 35-51.

GOBSTER, P. H., NASSAUER, J. I., DANIEL, T. C. & FRY, G. 2007. The shared landscape: what does aesthetics have to do with ecology? *Landscape Ecology,* 22**,** 959-972.

GRAY, C. L., HILL, S. L. L., NEWBOLD, T., HUDSON, L. N., BÖRGER, L., CONTU, S., HOSKINS, A. J., FERRIER, S., PURVIS, A. & SCHARLEMANN, J. P. W. 2016. Local biodiversity is higher inside than outside terrestrial protected areas worldwide. *Nature Communications,* 7**,** 12306.

GREGORY, R. 2003. Not in my park: community opposition to the enhancement of urban biodiversity: a case study of Heywood Park. *GEOView Online Journal*.

GROSE, M. J. 2012. Plant colour as a visual aspect of biological conservation. *Biological Conservation,* 153**,** 159-163.

GUITE, H. F., CLARK, C. & ACKRILL, G. 2006. The impact of the physical and urban environment on mental well-being. *Public Health,* 120**,** 1117-26.

GUNNARSSON, B., KNEZ, I., HEDBLOM, M. & SANG, Å. O. 2017. Effects of biodiversity and environment-related attitude on perception of urban green space. *Urban Ecosystems,* 20**,** 37-49.

GYLLIN, M. & GRAHN, P. 2005. A semantic model for assessing the experience of urban biodiversity. *Urban Forestry & Urban Greening,* 3**,** 149-161.

HARTIG, T., EVANS, G. W., JAMNER, L. D., DAVIS, D. S. & GARLING, T. 2003. Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology,* 23**,** 109-123.

HARTIG, T., KORPELA, K., EVANS, G. W. & GARLING, T. 1997. A measure of restorative quality in environments. *Scandinavian Housing & Planning Research,* 14**,** 175-194.

HARTIG, T., MANG, M. & EVANS, G. W. 1991. Restorative effects of natural environment experiences. *Environment and Behavior,* 23**,** 3-26.

HARTIG, T., MITCHELL, R., DE VRIES, S. & FRUMKIN, H. 2014. Nature and health. *Annu Rev Public Health,* 35**,** 207-28.

HARTIG, T. & STAATS, H. 2006. The need for psychological restoration as a determinant of environmental preferences. *Journal of Environmental Psychology,* 26**,** 215-226.

HASSOL, S. J. 2008. Improving How Scientists Communicate About Climate Change. *Eos, Transactions American Geophysical Union,* 89**,** 106-107.

HAWN, S. E., PAUL, L., THOMAS, S., MILLER, S. & AMSTADTER, A. B. 2015. Stress reactivity to an electronic version of the Trier Social Stress Test: a pilot study. *Frontiers in psychology,* 6**,** 724-724.

HERMY, M. & CORNELIS, J. 2000. Towards a monitoring method and a number of multifaceted and hierarchical biodiversity indicators for urban and suburban parks. *Landscape and Urban Planning,* 49**,** 149-162.

HILL, D. & DANIEL, T. C. 2007. Foundations for an Ecological Aesthetic: Can Information Alter Landscape Preferences? *Society & Natural Resources,* 21**,** 34-49.

HODGSON, R. W. & THAYER, R. L. 1980. Implied human influence reduces landscape beauty. *Landscape Planning,* 7**,** 171-179.

HONNAY, O., PIESSENS, K., VAN LANDUYT, W., HERMY, M. & GULINCK, H. 2003. Satellite based land use and landscape complexity indices as predictors for regional plant species diversity. *Landscape and Urban Planning,* 63**,** 241-250.

HORWITZ, P., LINDSAY, M. & O'CONNOR, M. 2001. Biodiversity, Endemism, Sense of Place, and Public Health: Inter-relationships for Australian Inland Aquatic Systems. *Ecosystem Health,* 7**,** 253-265.

HOYLE, H., HITCHMOUGH, J. & 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**,** 109-123.

HSIEH, H. F. & SHANNON, S. E. 2005. Three approaches to qualitative content analysis. *Qual Health Res,* 15**,** 1277-88.

HUNTER, L. M. & BREHM, J. 2003. Qualitative Insight into Public Knowledge of, and Concern with, Biodiversity. *Human Ecology,* 31**,** 309-320.

IGNATIEVA, M. E. & STEWART, G. H. 2009. Homogeneity of urban biotopes and similarity of landscape design language in former colonial cities. *In:* HAHS, A. K., BREUSTE, J. H. & MCDONNELL, M. J. (eds.) *Ecology of Cities and Towns: A Comparative Approach.* Cambridge: Cambridge University Press.

INGRAM, J. C., REDFORD, K. H. & WATSON, J. E. M. 2012. Applying Ecosystem Services Approaches for Biodiversity Conservation: Benefits and Challenges. *S.A.P.I.EN.S,* 5.

IRVINE, K. N., WARBER, S. L., DEVINE-WRIGHT, P. & GASTON, K. J. 2013. Understanding urban green space as a health resource: a qualitative comparison of visit motivation and derived effects among park users in Sheffield, UK. *Int J Environ Res Public Health,* 10**,** 417-42.

JACOBS, B., MIKHAILOVICH, N. & DELANEY, C. 2014. Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment *Prepared for Horticulture Australia Limited.* University of Technology Sydney.

JOHANSSON, M., GYLLIN, M., WITZELL, J. & KÜLLER, M. 2014. Does biological quality matter? Direct and reflected appraisal of biodiversity in temperate deciduous broad-leaf forest. *Urban Forestry & Urban Greening,* 13**,** 28-37.

JOHNSON, R. B. & ONWUEGBUZIE, A. J. 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher,* 33**,** 14-26.

JÖNSSON, P., WALLERGÅRD, M., ÖSTERBERG, K., HANSEN, Å. M., JOHANSSON, G. & KARLSON, B. 2010. Cardiovascular and cortisol reactivity and habituation to a virtual reality version of the Trier Social Stress Test: A pilot study. *Psychoneuroendocrinology,* 35**,** 1397-1403.

JORGENSEN, A. & GOBSTER, P. H. 2010. Shades of Green: Measuring the Ecology of Urban Green Space in the Context of Human Health and Well-Being. *Nature + Culture,* 5**,** 338-363.

JORGENSEN, A., WILSON, E. & VAN DEN BERG, A. E. 2010. Evaluating stress relief in urban green and open spaces: Does perceived naturaless make a difference? . *Paper presented at 'Trees and Forests in British Society' Conference.* Heriott Watt University, Edinburgh UK.

JOYE, Y., PALS, R., STEG, L. & EVANS, B. L. 2013. New methods for assessing the fascinating nature of nature experiences. *PLoS One,* 8**,** e65332.

JOYE, Y. & VAN DEN BERG, A. E. 2013. Restorative Environments. *In:* STEG, L., VAN DEN BERG, A. E. & DE GROOT, J. I. M. (eds.) *Environmental Psychology: an Introduction.* West Sussex: BPS Blackwell.

KACZYNSKI, A. T., STANIS, S. A. & BESENYI, G. M. 2012. Development and testing of a community stakeholder park audit tool. *Am J Prev Med,* 42**,** 242-9.

KAHN, P. H. & KELLERT, S. R. 2002. *Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations,* MIT Press.

KALS, E., SCHUMACHER, D. & MONTADA, L. 1999. Emotional Affinity toward Nature as a Motivational Basis to Protect Nature. *Environment and Behavior,* 31**,** 178-202.

KAPLAN, R. 1985. The analysis of perception via preference: A strategy for studying how the environment is experienced. *Landscape Planning,* 12**,** 161-176.

KAPLAN, R. & KAPLAN, S. 1989. *The experience of nature: a psychological perspective,* Cambridge University Press.

KAPLAN, S. 1995. The Restorative Benefits of Nature - toward an Integrative Framework. *Journal of Environmental Psychology,* 15**,** 169-182.

KARMANOV, D. & HAMEL, R. 2008. Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning,* 86**,** 115-125.

KEESING, F., BELDEN, L. K., DASZAK, P., DOBSON, A., HARVELL, C. D., HOLT, R. D., HUDSON, P., JOLLES, A., JONES, K. E., MITCHELL, C. E., MYERS, S. S., BOGICH, T. & OSTFELD, R. S. 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature,* 468**,** 647-652.

KELLERT, S. R. 1993. The biological basis for human values of nature. *In:* WILSON, E. O. & KELLERT, S. R. (eds.) *The Biophilia hypothesis.* Washington, D.C.: Island Press.

KENIGER, L. E., GASTON, K. J., IRVINE, K. N. & FULLER, R. A. 2013. What are the benefits of interacting with nature? *Int J Environ Res Public Health,* 10**,** 913-35.

KESEBIR, S. & KESEBIR, P. 2017. A Growing Disconnection From Nature Is Evident in Cultural Products. *Perspect Psychol Sci,* 12**,** 258-269.

KIM, T. & BIOCCA, F. 1997. Telepresence via Television: Two Dimensions of Telepresence May Have Different Connections to Memory and Persuasion.[1]. *Journal of Computer-Mediated Communication,* 3**,** 0-0.

KIRSCHBAUM, C., PIRKE, K.-M. & HELLHAMMER, D. H. 1993. The "Trier Social Stress Test": A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology,* 28**,** 76-81.

KORPELA, K. M. 1989. Place-Identity as a Product of Environmental Self-Regulation. *Journal of Environmental Psychology,* 9**,** 241-256.

KORPELA, K. M. Are favourite places restorative environments? *In:* URBINA-SORIA, J., ORTEGA-ANDEANE, P. & BECHTEL, R., eds. Healthy Environments. Proceedings of the 22nd annual conference of the Environmental Design Research Association, 1991 Oklahoma. EDRA.

KORPELA, K. M. 1992. Adolescents Favorite Places and Environmental Self-Regulation. *Journal of Environmental Psychology,* 12**,** 249-258.

KORPELA, K. M. & HARTIG, T. 1996. Restorative qualities of favorite places. *Journal of Environmental Psychology,* 16**,** 221-233.

KORPELA, K. M., HARTIG, T., KAISER, F. G. & FUHRER, U. 2001. Restorative experience and self-regulation in favorite places. *Environment and Behavior,* 33**,** 572-589.

KORPELA, K. M. & YLEN, M. 2007. Perceived health is associated with visiting natural favourite places in the vicinity. *Health & Place,* 13**,** 138-151.

KORPELA, K. M., YLEN, M., TYRVAINEN, L. & SILVENNOINEN, H. 2008. Determinants of restorative experiences in everyday favorite places. *Health & Place,* 14**,** 636-652.

KORPELA, K. M., YLEN, M., TYRVAINEN, L. & SILVENNOINEN, H. 2009. Stability of self-reported favourite places and place attachment over a 10-month period. *Journal of Environmental Psychology,* 29**,** 95-100.

KORPELA, K. M., YLEN, M., TYRVAINEN, L. & SILVENNOINEN, H. 2010. Favorite green, waterside and urban environments, restorative experiences and perceived health in Finland. *Health Promotion International,* 25**,** 200-209.

KORPELA, K. M. & YLEN, M. P. 2009. Effectiveness of Favorite-Place Prescriptions A Field Experiment. *American Journal of Preventive Medicine,* 36**,** 435-438.

KORPILO, S., VIRTANEN, T., SAUKKONEN, T. & LEHVÄVIRTA, S. 2018. More than A to B: Understanding and managing visitor spatial behaviour in urban forests using public participation GIS. *Journal of Environmental Management,* 207**,** 124-133.

LAMB, R. J. & PURCELL, A. T. 1990. Perception of Naturalness in Landscape and Its Relationship to Vegetation Structure. *Landscape and Urban Planning,* 19**,** 333-352.

LANG, T. & RAYNER, G. 2012. Ecological public health: the 21st century's big idea? An essay by Tim Lang and Geof Rayner. *BMJ,* 345**,** e5466.

LEDERBOGEN, F., KIRSCH, P., HADDAD, L., STREIT, F., TOST, H., SCHUCH, P., WÜST, S., PRUESSNER, J. C., RIETSCHEL, M., DEUSCHLE, M. & MEYER-LINDENBERG, A. 2011. City living and urban upbringing affect neural social stress processing in humans. *Nature,* 474**,** 498.

LEE, A. C. & MAHESWARAN, R. 2011. The health benefits of urban green spaces: a review of the evidence. *J Public Health (Oxf),* 33**,** 212-22.

LEE, R., HEINRICH, K., REESE-SMITH, J., REGAN, G. & H HOWARD, H. 2005. *The Physical Activity Resource Assessment (PARA) instrument: Evaluating features, amenities and incivilities of physical activity resources in urban neighborhoods*.

LGASA 2014. Open Space Contribution and Funding Analysis: Discussion Paper. South Australia: Local Government Association of South Australia.

LI, Y., JOHNSON, E. J. & ZAVAL, L. 2011. Local warming: daily temperature change influences belief in global warming. *Psychol Sci,* 22**,** 454-9.

LINDEMANN-MATTHIES, P. 2002. The Influence of an Educational Program on Children's Perception of Biodiversity. *The Journal of Environmental Education,* 33**,** 22-31.

LINDEMANN-MATTHIES, P. & BOSE, E. 2008. How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland. *Human Ecology,* 36**,** 731-742.

LINDEMANN-MATTHIES, P., JUNGE, X. & MATTHIES, D. 2010. The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. *Biological Conservation,* 143**,** 195-202.

LIVINGSTON, M., SHAW, W. W. & HARRIS, L. K. 2003. A model for assessing wildlife habitats in urban landscapes of eastern Pima County, Arizona (USA). *Landscape and Urban Planning,* 64**,** 131-144.

LOUV, R. 2008. *Last Child in the Woods: Saving Our Children From Nature-Deficit Disorder,* Algonquin Books.

LOVELL, R., WHEELER, B. W., HIGGINS, S. L., IRVINE, K. N. & DEPLEDGE, M. H. 2014. A systematic review of the health and well-being benefits of biodiverse environments. *J Toxicol Environ Health B Crit Rev,* 17**,** 1-20.

LUCK, G. W., DAVIDSON, P., BOXALL, D. & SMALLBONE, L. 2011. Relations between Urban Bird and Plant Communities and Human Well-Being and Connection to Nature

Relaciones entre las Comunidades de Aves y Plantas Urbanas y el Bienestar Humano y la Conexión con la Naturaleza. *Conservation Biology,* 25**,** 816-826.

MAAS, J., VERHEIJ, R. A., GROENEWEGEN, P. P., DE VRIES, S. & SPREEUWENBERG, P. 2006. Green space, urbanity, and health: how strong is the relation? *J Epidemiol Community Health,* 60**,** 587-92.

MACE, G. M., NORRIS, K. & FITTER, A. H. 2012. Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology & Evolution,* 27**,** 19-26.

MACHADO, A. 2004. An index of naturalness. *Journal for Nature Conservation,* 12**,** 95-110.

MACKERRON, G. & MOURATO, S. 2013. Happiness is greater in natural environments. *Global Environmental Change-Human and Policy Dimensions,* 23**,** 992-1000.

MALLER, C., TOWNSEND, M., LEGER, L., HENDERSON-WILSON, C., PRYOR, A., PROSSER, L. & MOORE, M. 2008. Healthy parks, healthy people: the health benefits of contact with nature in a park context. *Deakin University and Parks Victoria Melbourne*.

MALLER, C., TOWNSEND, M., PRYOR, A., BROWN, P. & ST LEGER, L. 2006. Healthy nature healthy people: 'contact with nature' as an upstream health promotion intervention for populations. *Health Promot Int,* 21**,** 45-54.

MANFREDO, M. J., DRIVER, B. L. & TARRANT, M. A. 1996. Measuring Leisure Motivation: A Meta-Analysis of the Recreation Experience Preference Scales. *Journal of Leisure Research,* 28**,** 188-213.

MARSELLE, M. R., IRVINE, K. N., LORENZO-ARRIBAS, A. & WARBER, S. L. 2015. Moving beyond Green: Exploring the Relationship of Environment Type and Indicators of Perceived Environmental Quality on Emotional Well-Being following Group Walks. *International Journal of Environmental Research and Public Health,* 12**,** 106-130.

MARSELLE, M. R., IRVINE, K. N. & WARBER, S. L. 2013. Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks in urban environments? *Int J Environ Res Public Health,* 10**,** 5603-28.

MARTENS, D., GUTSCHER, H. & BAUER, N. 2011. Walking in "wild" and "tended" urban forests: The impact on psychological well-being. *Journal of Environmental Psychology,* 31**,** 36-44.

MARTÍN-LÓPEZ, B., MONTES, C. & BENAYAS, J. 2007. The non-economic motives behind the willingness to pay for biodiversity conservation. *Biological Conservation,* 139**,** 67-82.

MBINA, A. A. & EDEM, E. E. 2015. The role of colours in the health and wellbeing of the built environment in the tropics. *European Journal of Research in Social Sciences,* 3**,** 81-87.

MCCORMACK, G. R., ROCK, M., TOOHEY, A. M. & HIGNELL, D. 2010. Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. *Health Place,* 16**,** 712-26.

MCDONALD, R. I., CHAI, H. Y. & NEWELL, B. R. 2015. Personal experience and the 'psychological distance' of climate change: An integrative review. *Journal of Environmental Psychology,* 44**,** 109-118.

MCDONALD, R. I., FORMAN, R. T. & KAREIVA, P. 2010. Open space loss and land inequality in United States' cities, 1990-2000. *PLoS One,* 5**,** e9509.

MEDVEDEV, O., SHEPHERD, D. & HAUTUS, M. J. 2015. The restorative potential of soundscapes: A physiological investigation. *Applied Acoustics,* 96**,** 20-26.

MEIJLES, E. W., DE BAKKER, M., GROOTE, P. D. & BARSKE, R. 2014. Analysing hiker movement patterns using GPS data: Implications for park management. *Computers, Environment and Urban Systems,* 47**,** 44-57.

MERTES, J. D. & HALL, J. R. 1996. Park, recreation, open space and greenway guidelines. *In:* ASSOCIATION, N. R. A. P. (ed.). USA: National Recreation and Park Association.

MILES, J. C. 1991. Teaching in Wilderness. *The Journal of Environmental Education,* 22.

MILLENNIUM ECOSYSTEM ASSESSMENT 2005. *Ecosystems and Human Well-being: Synthesis,* Island Press.

MILLER, J. R. 2005. Biodiversity conservation and the extinction of experience. *Trends Ecol Evol,* 20**,** 430-4.

MONTERO-LÓPEZ, E., SANTOS-RUIZ, A., GARCÍA-RÍOS, M. C., RODRÍGUEZ-BLÁZQUEZ, R., PÉREZ-GARCÍA, M. & PERALTA-RAMÍREZ, M. I. 2016. A virtual reality approach to the Trier Social Stress Test: Contrasting two distinct protocols. *Behavior Research Methods,* 48**,** 223-232.

MOORE, R. L. & DRIVER, B. L. 2005a. *Introduction to Outdoor Education: Providing and Managing Natural Resource Based Opportunities,* State College, PA, Venture Publishing, inc.

MOORE, R. L. & DRIVER, B. L. 2005b. *Introduction to Outdoor Recreation: Providing and Managing Natural Resource Based Opportunities*, Venture Pub.

MORGAN, P. 2010. Towards a developmental theory of place attachment. *Journal of Environmental Psychology,* 30**,** 11-22.

MURATET, A., PELLEGRINI, P., DUFOUR, A.-B., ARRIF, T. & CHIRON, F. 2015. Perception and knowledge of plant diversity among urban park users. *Landscape and Urban Planning,* 137**,** 95-106.

MYERS, N., MITTERMEIER, R. A., MITTERMEIER, C. G., DA FONSECA, G. A. B. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature,* 403**,** 853.

NASSAUER, J. I. 1995. Messy Ecosystems, Orderly Frames. *Landscape Journal,* 14**,** 161-170.

NEWELL, P. B. 1997. A cross-cultural examination of favorite places. *Environment and Behavior,* 29**,** 495-514.

NIELSEN, A. B., VAN DEN BOSCH, M., MARUTHAVEERAN, S. & VAN DEN BOSCH, C. K. 2014. Species richness in urban parks and its drivers: A review of empirical evidence. *Urban Ecosystems,* 17**,** 305-327.

NISBET, E. K., ZELENSKI, J. M. & MURPHY, S. A. 2009. The Nature Relatedness Scale. *Environment and Behavior,* 41**,** 715-740.

NORDH, H., HARTIG, T., HAGERHALL, C. M. & FRY, G. 2009. Components of small urban parks that predict the possibility for restoration. *Urban Forestry & Urban Greening,* 8**,** 225-235.

NOVACEK, M. J. 2008. Engaging the public in biodiversity issues. *Proceedings of the National Academy of Sciences,* 105**,** 11571-11578.

O'BRIEN, L., TOWNSEND, M. & EBDEN, M. 2008. Environmental volunteering: motivations, barriers and benefits. *Scottish Forestry Trust and Forestry Commission.*

ORIANS, G. H. 1980. Habitat selection : General theory and applications to human behavior. *The evolution of human social behavior*.

OSORIO, D. & VOROBYEV, M. 1996. Colour vision as an adaptation to frugivory in primates. *Proc Biol Sci,* 263**,** 593-9.

OSTFELD, R. S. 2017. Biodiversity loss and the ecology of infectious disease. *The Lancet Planetary Health,* 1**,** e2-e3.

PARÉS-FRANZI, M., SAURÍ-PUJOL, D. & DOMENE, E. 2006. Evaluating the Environmental Performance of Urban Parks in Mediterranean Cities: An Example from the Barcelona Metropolitan Region. *Environmental Management,* 38**,** 750-759.

PARKS VICTORIA. A guide to the healthy parks healthy people approach and current practices: proceedings from the Improving Health and Well-being: Healthy Parks Healthy People stream. IUCN World Parks Congress, 2015 Sydney, Australia. Parks Victoria.

PARSONS, R. & DANIEL, T. C. 2002. Good looking: in defense of scenic landscape aesthetics. *Landscape and Urban Planning,* 60**,** 43-56.

PAULEIT, S. & DUHME, F. 2000. Assessing the environmental performance of land cover types for urban planning. *Landscape and Urban Planning,* 52**,** 1-20.

PAYKEL, E. S., ABBOTT, R., JENKINS, R., BRUGHA, T. S. & MELTZER, H. 2000. Urban-rural mental health differences in great Britain: findings from the national morbidity survey. *Psychol Med,* 30**,** 269-80.

PEEN, J., SCHOEVERS, R. A., BEEKMAN, A. T. & DEKKER, J. 2010. The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatr Scand,* 121**,** 84-93.

PELLICO, L. H., FRIEDLAENDER, L. & FENNIE, K. P. 2009. Looking is not seeing: using art to improve observational skills. *J Nurs Educ,* 48**,** 648-53.

PERKINS, N. H. & BROWN, R. D. 1999. Environmental aesthetics. *Environmental Geology*. Dordrecht: Springer Netherlands.

PETERSON, G., ALLEN, C. R. & HOLLING, C. S. 1998. Ecological Resilience, Biodiversity, and Scale. *Ecosystems,* 1**,** 6-18.

PETT, T. J., SHWARTZ, A., IRVINE, K. N., DALLIMER, M. & DAVIES, Z. G. 2016. Unpacking the People–Biodiversity Paradox: A Conceptual Framework. *BioScience,* 66**,** 576-583.

PICARD, R. W., FEDOR, S. & AYZENBERG, Y. 2015. Multiple Arousal Theory and Daily-Life Electrodermal Activity Asymmetry. *Emotion Review,* 8**,** 62-75.

PITMAN, S. 2010. Council Solutions. *In:* DANIELS, C. B. (ed.) *Adelaide: Water of a City.* Adelaide: Wakefield Press.

PITMAN, S. D. & DANIELS, C. B. 2016. Quantifying Ecological Literacy in an Adult Western Community: The Development and Application of a New Assessment Tool and Community Standard. *PLoS One,* 11**,** e0150648.

PITMAN, S. D., DANIELS, C. B. & SUTTON, P. C. 2018. Ecological literacy and socio-demographics: who are the most eco-literate in our community, and why? *International Journal of Sustainable Development & World Ecology,* 25**,** 9-22.

POH, M., SWENSON, N. C. & PICARD, R. W. 2010. A Wearable Sensor for Unobtrusive, Long-Term Assessment of Electrodermal Activity. *IEEE Transactions on Biomedical Engineering,* 57**,** 1243-1252.

PRATT, J., RADULESCU, P. V., GUO, R. M. & ABRAMS, R. A. 2010. It's alive! animate motion captures visual attention. *Psychol Sci,* 21**,** 1724-30.

PYLE, R. M. 2002. *Eden in a vacant lot: special places, species, and kids in the neighborhood of life,* MIT Press.

QIU, L., LINDBERG, S. & NIELSEN, A. B. 2013. Is biodiversity attractive?—On-site perception of recreational and biodiversity values in urban green space. *Landscape and Urban Planning,* 119**,** 136-146.

QIU, L. & NIELSEN, A. B. 2015. Are Perceived Sensory Dimensions a Reliable Tool for Urban Green Space Assessment and Planning? *Landscape Research,* 40**,** 834-854.

RANDS, M. R., ADAMS, W. M., BENNUN, L., BUTCHART, S. H., CLEMENTS, A., COOMES, D., ENTWISTLE, A., HODGE, I., KAPOS, V. & SCHARLEMANN, J. P. 2010. Biodiversity conservation: challenges beyond 2010. *Science,* 329**,** 1298-1303.

RATCLIFFE, E., GATERSLEBEN, B. & SOWDEN, P. T. 2013. Bird sounds and their contributions to perceived attention restoration and stress recovery. *Journal of Environmental Psychology,* 36**,** 221-228.

RAXWORTHY, J. R. 2010. Dryness : the aesthetic condition of landscape design in Australia. *In:* PARODI, O. (ed.) *Towards Resilient Water Landscapes : Design Research Approaches from Europe and Australia.* Karlsruhe: KIT Scientific Publishing.

RELPH, E. 2008. Senses of Place and Emerging Social and Environmental Challenges. *In:* EYLES, J. & WILLIAMS, A. (eds.) *Sense of Place, Health and Quality of Life.* Ashgate.

RICHARDSON, E. A., MITCHELL, R., HARTIG, T., DE VRIES, S., ASTELL-BURT, T. & FRUMKIN, H. 2012. Green cities and health: a question of scale? *J Epidemiol Community Health,* 66**,** 160-5.

RICHARDSON, M., HALLAM, J. & LUMBER, R. 2015. One Thousand Good Things in Nature: Aspects of Nearby Nature Associated with Improved Connection to Nature. *Environmental Values,* 24**,** 603-619.

RICHARDSON, M. & 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**,** 1-32.

RIDDER, B. 2007. An exploration of the value of naturalness and wild nature. *Journal of Agricultural & Environmental Ethics,* 20**,** 195-213.

ROBERTS, B. W., EDMONDS, G. & GRIJALVA, E. 2010. It Is Developmental Me, Not Generation Me: Developmental Changes Are More Important Than Generational Changes in Narcissism-Commentary on Trzesniewski & Donnellan (2010). *Perspect Psychol Sci,* 5**,** 97-102.

ROBERTSON, D. P. & HULL, R. B. 2001. Beyond Biology: toward a More Public Ecology for Conservation

Más allá de la Biología: Hacia una Ecología más Pública para la Conservación. *Conservation Biology,* 15**,** 970-979.

ROGERS, K. & JALUZOT, A. 2015. Oxford i-Tree Canopy Cover Assessment: Oxford City Council, United Kingdom

ROLLERO, C. & DE PICCOLI, N. 2010. Place attachment, identification and environment perception: An empirical study. *Journal of Environmental Psychology,* 30**,** 198-205.

ROSSMAN, G. B. & WILSON, B. L. 1985. Numbers and Words:Combining Quantitative and Qualitative Methods in a Single Large-Scale Evaluation Study. *Evaluation Review,* 9**,** 627-643.

RUDDELL, E. J., GRAMANN, J. H., RUDIS, V. A. & WESTPHAL, J. M. 1989. The Psychological Utility of Visual Penetration in near-view Forest Scenic-Beauty Models. *Environment and Behavior,* 21**,** 393-412.

RUDDELL, E. J. & HAMMITT, W. E. 1987. Prospect Refuge Theory: A Psychological Orientation for Edge Effect in Recreation Environments. *Journal of Leisure Research,* 19**,** 249-260.

SAELENS, B. E., FRANK, L. D., AUFFREY, C., WHITAKER, R. C., BURDETTE, H. L. & COLABIANCHI, N. 2006. Measuring Physical Environments of Parks and Playgrounds: EAPRS Instrument Development and Inter-Rater Reliability. *Journal of Physical Activity and Health,* 3**,** S190-S207.

SANDIFER, P. A., SUTTON-GRIER, A. E. & 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**,** 1-15.

SCHEBELLA, M. F., WEBER, D., LINDSEY, K. & DANIELS, C. B. 2017. For the Love of Nature: Exploring the Importance of Species Diversity and Micro-Variables Associated with Favorite Outdoor Places. *Front Psychol,* 8**,** 2094.

SCHEBELLA, M. F., WEBER, D., WEINSTEIN, P. & SCHULTZ, L. 2018. In Pursuit of Urban Sustainability: predicting public perceptions of park biodiversity using simple assessment tools. *International Journal of Environmental Research*

SCOPELLITI, M., CARRUS, G., CINI, F., MASTANDREA, S., FERRINI, F., LAFORTEZZA, R., AGRIMI, M., SALBITANO, F., SANESI, G. & SEMENZATO, P. 2012. Biodiversity, Perceived Restorativeness and Benefits of Nature: A Study on the Psychological Processes and Outcomes of On-Site Experiences in Urban and Peri-Urban Green Areas in Italy. *In:* KABISCH, S., KUNATH, A., SCHWEIZER-RIES, P. & STEINFUHRER, A. (eds.) *Vulnerability, Risks, and Complexity: Impacts of Global Change on Human Habitats.* Cambridge, MA: Hogrefe Publishing.

SHANAHAN, D. F., BUSH, R., GASTON, K. J., LIN, B. B., DEAN, J., BARBER, E. & FULLER, R. A. 2016. Health Benefits from Nature Experiences Depend on Dose. *Scientific Reports,* 6**,** 28551.

SHANAHAN, D. F., LIN, B. B., BUSH, R., GASTON, K. J., DEAN, J. H., BARBER, E. & FULLER, R. A. 2015a. Toward improved public health outcomes from urban nature. *American journal of public health,* 105**,** 470-477.

SHANAHAN, D. F., LIN, B. B., GASTON, K. J., BUSH, R. & FULLER, R. A. 2015b. What is the role of trees and remnant vegetation in attracting people to urban parks? *Landscape Ecology,* 30**,** 153-165.

SHWARTZ, A., TURBÉ, A., SIMON, L. & JULLIARD, R. 2014. Enhancing urban biodiversity and its influence on city-dwellers: An experiment. *Biological Conservation,* 171**,** 82-90.

SIKORSKA, D., SIKORSKI, P. & HOPKINS, R. 2017. High Biodiversity of Green Infrastructure Does Not Contribute to Recreational Ecosystem Services. *Sustainability,* 9**,** 334.

SIMAIKA, J. P. & SAMWAYS, M. J. 2010. Biophilia as a Universal Ethic for Conserving Biodiversity. *Conservation Biology,* 24**,** 903-906.

SIMPSON, K. & DAY, N. 2004. *Field Guide to the Birds of Australia,* Australia, Penguin Group.

SIVAM, A., KARUPPANNAN, S. & MOBBS, M. 2012. How "open" are open spaces: evaluating transformation of open space at residential level in Adelaide – a case study. *Local Environment,* 17**,** 815-836.

SMITH, J. 2015. Immersive Virtual Environment Technology to Supplement Environmental Perception, Preference and Behavior Research: A Review with Applications. *International Journal of Environmental Research and Public Health,* 12**,** 11486.

SOUTH AUSTRALIAN GOVERNMENT. 2014. *About SA* [Online]. South Australia: South Australian Department of the Premier and Cabinet. Available: https://www.sa.gov.au/about-sa [Accessed 11 April 2016].

STEG, L. & DE GROOT, J. I. M. 2013. *Environmental Psychology: An Introduction,* Wiley.

STEIN, A., GERSTNER, K. & KREFT, H. 2014. Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecology Letters,* 17**,** 866-880.

STIGLITZ, J., SEN, A. & FITOUSSI, J.-P. 2010. Report by the Commission on the Measurement of Economic Performance and Social Progress. Paris.

STOKES, D. L. 2007. Things We Like: Human Preferences among Similar Organisms and Implications for Conservation. *Human Ecology,* 35**,** 361-369.

TAGLES, H. D. & IDROVO, A. J. 2012. Biodiversity and mental health. *Biodiversity Enrichment in a Diverse World.* InTech.

TAYLOR, A. F. & KUO, F. E. 2009. Children with attention deficits concentrate better after walk in the park. *J Atten Disord,* 12**,** 402-9.

TAYLOR, L. & HOCHULI, D. F. 2017. Defining greenspace: Multiple uses across multiple disciplines. *Landscape and Urban Planning,* 158**,** 25-38.

THE UNITED NATIONS 2014. World Urbanization Prospects: The 2014 Revision. The United Nations Department of Economic and Social Affairs, Population Division.

THOMPSON, J. L., KAISER, A., SPARKS, E. L., SHELTON, M., BRUNDEN, E., CHERRY, J. A. & CEBRIAN, J. 2016. Ecosystem – What? Public Understanding and Trust in Conservation Science and Ecosystem Services. *Frontiers in Communication,* 1.

TILMAN, D. 1996. Biodiversity: Population Versus Ecosystem Stability. *Ecology,* 77**,** 350-363.

TILMAN, D. 2000. Causes, consequences and ethics of biodiversity. *Nature,* 405**,** 208-211.

TILMAN, D., ISBELL, F. & COWLES, J. M. 2014. Biodiversity and Ecosystem Functioning. *Annual Review of Ecology, Evolution, and Systematics,* 45**,** 471-493.

TOWNSEND, M. & WEERASURIYA, R. 2010. Beyond Blue to Green: The benefits of contact with nature for mental health and well-being. Melbourne, Australia: Beyond Blue Limited.

TSUNETSUGU, Y., PARK, B. J. & MIYAZAKI, Y. 2010. Trends in research related to "Shinrin-yoku" (taking in the forest atmosphere or forest bathing) in Japan. *Environ Health Prev Med,* 15**,** 27-37.

TUAN, Y. F. 1974. *Topophilia: A Study of Environmental Perception, Attitudes, and Values,* Prentice-Hall.

TURNER-ERFORT, G. 1997. Public awareness and perceptions of biodiversity. *Transactions of the Illinois State Academy of Science,* 90**,** 113-121.

TWENGE, J. M., KONRATH, S., FOSTER, J. D., CAMPBELL, W. K. & BUSHMAN, B. J. 2008. Egos inflating over time: a cross-temporal meta-analysis of the Narcissistic Personality Inventory. *J Pers,* 76**,** 875-902; discussion 903-28.

TZOULAS, K. & JAMES, P. 2010. Making biodiversity measures accessible to non-specialists: an innovative method for rapid assessment of urban biodiversity. *Urban Ecosystems,* 13**,** 113-127.

ULRICH, R. S. 1983. Aesthetic and Affective Response to Natural Environment. *In:* ALTMAN, I. & WOHLWILL, J. F. (eds.) *Behavior and the Natural Environment.* Boston, MA: Springer US.

ULRICH, R. S. 1984. View through a Window May Influence Recovery from Surgery. *Science,* 224**,** 420-421.

ULRICH, R. S. 1986. Human responses to vegetation and landscapes. *Landscape and Urban Planning,* 13**,** 29-44.

ULRICH, R. S., SIMONS, R. F., LOSITO, B. D., FIORITO, E., MILES, M. A. & ZELSON, M. 1991. Stress Recovery during Exposure to Natural and Urban Environments. *Journal of Environmental Psychology,* 11**,** 201-230.

UNITED NATIONS 1992. Convention on Biological Diversity. *1760 UNTS 79; 31 ILM 818*

UNITED NATIONS 2010. Strategic Plan for Biodiversity 2011-2020: Provisional Technical Rationale, Possible Indicators and Suggested Milestones for the Aichi Biodiveristy Targets. *Conference of the Parties to the Convention on Biological Diversity, Tenth Meeting.*

VAN DEN BERG, A. E. & CUSTERS, M. H. 2011. Gardening promotes neuroendocrine and affective restoration from stress. *J Health Psychol,* 16**,** 3-11.

VAN DEN BERG, A. E., HARTIG, T. & STAATS, H. 2007. Preference for Nature in Urbanized Societies: Stress, Restoration, and the Pursuit of Sustainability. *Journal of Social Issues,* 63**,** 79-96.

VAN DEN BERG, A. E., JORGENSEN, A. & WILSON, E. R. 2014. Evaluating restoration in urban green spaces: Does setting type make a difference? *Landscape and Urban Planning,* 127**,** 173-181.

VAN DOOREN, M., DE VRIES, J. J. G. & JANSSEN, J. H. 2012. Emotional sweating across the body: Comparing 16 different skin conductance measurement locations. *Physiology & Behavior,* 106**,** 298-304.

VAN HEEZIK, Y. & BRYMER, E. 2018. Nature as a Commodity: What's Good for Human Health Might Not Be Good for Ecosystem Health. *Frontiers in Psychology,* 9.

VAN RENSBURG, B. J., PEACOCK, D. S. & ROBERTSON, M. P. 2009. Biotic homogenization and alien bird species along an urban gradient in South Africa. *Landscape and Urban Planning,* 92**,** 233-241.

VASKE, J. J. & KOBRIN, K. C. 2010. Place Attachment and Environmentally Responsible Behavior. *The Journal of Environmental Education,* 32**,** 16-21.

VELARDE, M. D., FRY, G. & TVEIT, M. 2007. Health effects of viewing landscapes – Landscape types in environmental psychology. *Urban Forestry & Urban Greening,* 6**,** 199-212.

VOLLAARD, N. B. J., CONSTANTIN-TEODOSIU, D., FREDRIKSSON, K., ROOYACKERS, O., JANSSON, E., GREENHAFF, P. L., TIMMONS, J. A. & SUNDBERG, C. J. 2009. Systematic analysis of adaptations in aerobic capacity and submaximal energy metabolism provides a unique insight into determinants of human aerobic performance. *Journal of Applied Physiology,* 106**,** 1479-1486.

WALL, D. H., NIELSEN, U. N. & SIX, J. 2015. Soil biodiversity and human health. *Nature,* 528**,** 69.

WALLERGÅRD, M., JÖNSSON, P., JOHANSSON, G. & KARLSON, B. 2011. A Virtual Reality Version of the Trier Social Stress Test: A Pilot Study. *Presence,* 20**,** 325-336.

WANG, D., BROWN, G. & LIU, Y. 2015. The physical and non-physical factors that influence perceived access to urban parks. *Landscape and Urban Planning,* 133**,** 53-66.

WARM, J. S., DEMBER, W. N. & PARASURAMAN, R. 1991. Effects of olfactory stimulation on performance and stress. *Journal of the Society Cosmetic Chemists,* 42**,** 199-210.

WEBER, D. & ANDERSON, D. 2010. Contact with nature: recreation experience preferences in Australian parks. *Annals of Leisure Research,* 13**,** 46-69.

WEBER, S. T. & HEUBERGER, E. 2008. The Impact of Natural Odors on Affective States in Humans. *Chemical Senses,* 33**,** 441-447.

WHITE, M. P., PAHL, S., ASHBULLBY, K., HERBERT, S. & DEPLEDGE, M. H. 2013. Feelings of restoration from recent nature visits. *Journal of Environmental Psychology,* 35**,** 40-51.

WHITFORD, V., ENNOS, A. R. & HANDLEY, J. F. 2001. "City form and natural process" - indicators for the ecological performance of urban areas and their application to Merseyside, UK. *Landscape and Urban Planning,* 57**,** 91-103.

WILLIAMS, D. R., PATTERSON, M. E., ROGGENBUCK, J. W. & WATSON, A. E. 1992. Beyond the Commodity Metaphor - Examining Emotional and Symbolic Attachment to Place. *Leisure Sciences,* 14**,** 29-46.

WILLIAMS, K. J. H. & CARY, J. 2002. Landscape Preferences, Ecological Quality, and Biodiversity Protection. *Environment and Behavior,* 34**,** 257-274.

WILSON, E. O. 1984. *Biophilia,* Massachusetts, Harvard University Press.

WIMPEY, J. & MARION, J. L. 2011. A spatial exploration of informal trail networks within Great Falls Park, VA. *Journal of Environmental Management,* 92**,** 1012-1022.

WINTER, S. 2012. Forest naturalness assessment as a component of biodiversity monitoring and conservation management. *Forestry,* 85**,** 293-304.

WITMER, B. G. & SINGER, M. J. 1998. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence: Teleoperators and Virtual Environments,* 7**,** 225-240.

WITTIG, R. & SCHREIBER, K.-F. 1983. A quick method for assessing the importance of open spaces in towns for urban nature conservation. *Biological Conservation,* 26**,** 57-64.

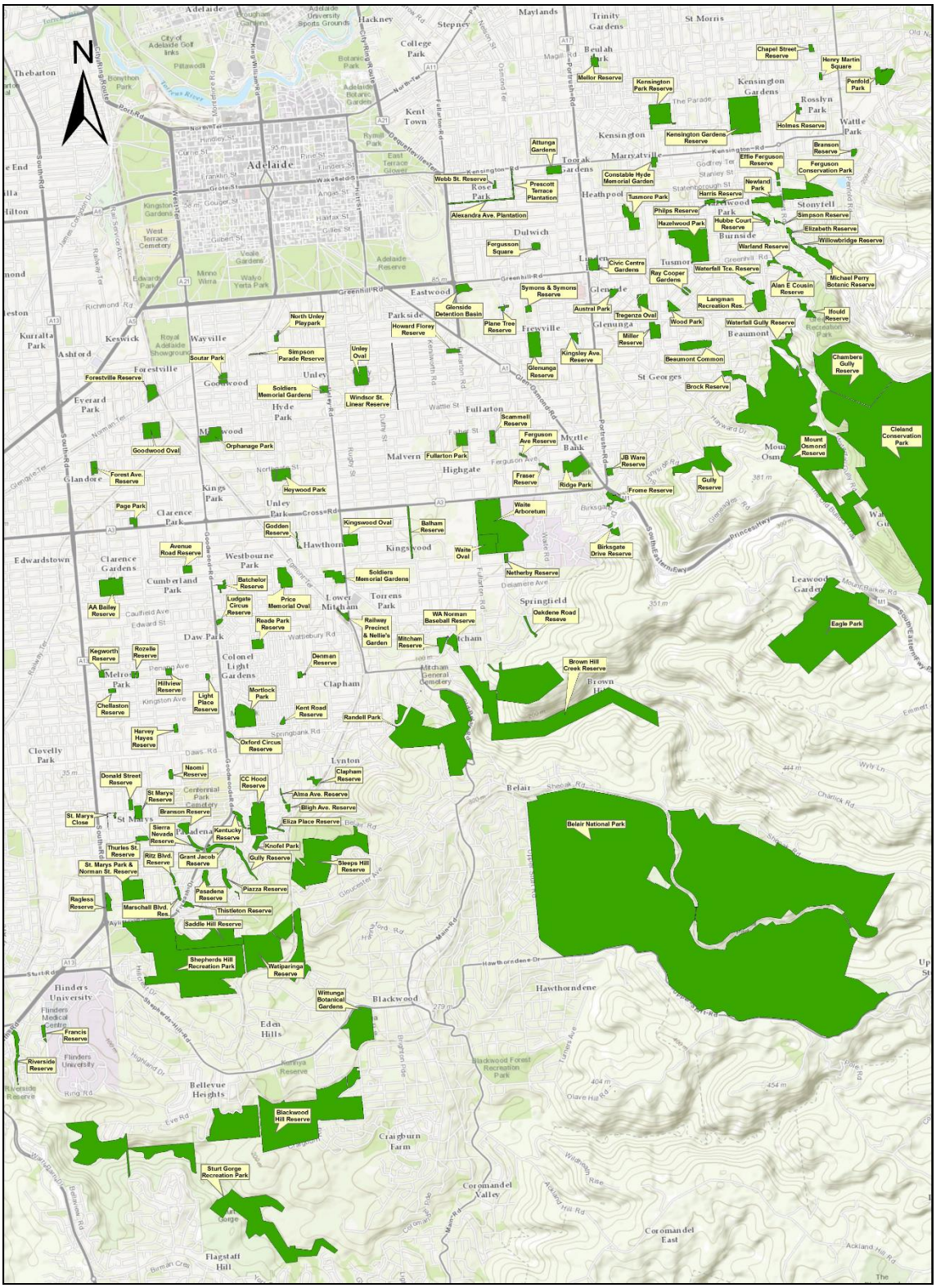
WOOD, E., HARSANT, A., DALLIMER, M., CRONIN DE CHAVEZ, A., MCEACHAN, R. R. C. & HASSALL, C. 2018. Not All Green Space Is Created Equal: Biodiversity Predicts Psychological Restorative Benefits From Urban Green Space. *Frontiers in Psychology,* 9.

YOUNG, C. H. & JARVIS, P. J. 2001a. Assessing the structural heterogeneity of urban areas: an example from the Black Country (UK). *Urban Ecosystems,* 5**,** 49-69.

YOUNG, C. H. & JARVIS, P. J. 2001b. A Simple Method for Predicting the Consequences of Land Management in Urban Habitats. *Environmental Management,* 28**,** 375-387.

ZIPPERER, W. C. & GUNTENSPERGEN, G. R. 2009. Vegetation composition and structure of forest patches along urban–rural gradients. *In:* HAHS, A. K., BREUSTE, J. H. & MCDONNELL, M. J. (eds.) *Ecology of Cities and Towns: A Comparative Approach.* Cambridge: Cambridge University Press.

Appendix A The map distributed to questionnaire respondents, highlighting the 134 green spaces in the study



Appendix B Operation Outdoors: Questions pertaining to my research



1. **What are your favourite "outdoor places" in South Australia?**

2. **What is it that you love most about these places?**

3. **What is your gender?**

4. **In what year were you born? (Please enter a 4-digit birth year, e.g. 1976)**

5. **Which lifecycle category best describes you? (Please select one category)**

- Young single
- Young couple, no children
- Young family (youngest child less than 6 years of age)
- Middle family (youngest child 6-15 years of age)
- Mature family (all children over 15 years of age)
- Older couple, no children at home
- Mature single

6. **Which of the following best describes the highest level of formal education you have completed? (Please select one response)**

- Primary/some secondary
- Secondary school
- Vocational/technical
- Some undergraduate tertiary study
- Bachelors degree or equivalent
- Postgraduate degree

Appendix C The Structural Elements Checklist. This table outlines the 31 structural elements in the checklist, the studies from which they were derived, and the items they were adapted from.

Category	Structural Element	Adapted/modified from
Individual Elements	1. Tall mature trees (>10m high)	***(Wittig and Schreiber, 1983)*** "Single trees" ***(Freeman, 1999)*** "Mature trees" ***(Hermy and Cornelis, 2000)*** "Single tree or shrub not surrounded by other trees or shrubs" ***(Young and Jarvis, 2001b)*** "Single trees" ***(Whitford et al., 2001)*** "Trees" ***(Young and Jarvis, 2001a)*** "Single trees" ***(Tzoulas and James, 2010)*** "High trees"
	2. Low mature trees and tall shrubs (5-9.9m high)	***(Wittig and Schreiber, 1983)*** "Single trees" ***(Freeman, 1999)*** "Mature trees" ***(Hermy and Cornelis, 2000)*** "Single tree or shrub not surrounded by other trees or shrubs" ***(Whitford et al., 2001)*** "Trees" ***(Young and Jarvis, 2001b)*** "Single trees" ***(Young and Jarvis, 2001a)*** "Single trees" ***(Tzoulas and James, 2010)*** "Low trees"
	3. Saplings	***(Young and Jarvis, 2001b)*** "Moss/lichens/seedlings"
	4. Dead trees	***(Young and Jarvis, 2001b)*** "Hollow trees of soft or dead wood" ***(Young and Jarvis, 2001a)*** "Dead wood"
	5. Standing trees with hollows	***(Young and Jarvis, 2001b)*** "Hollow trees of soft or dead wood" ***(Young and Jarvis, 2001a)*** "Dead wood"
	6. Bushes, shrubs (1 – 4.9m high)	***(Wittig and Schreiber, 1983)*** "Hedges and shrubbery" ***(Hermy and Cornelis, 2000)*** "Single tree or shrub not surrounded by other trees or shrubs" ***(Young and Jarvis, 2001b)*** "Hedges and shrubbery" ***(Whitford et al., 2001)*** "Shrubs" ***(Tzoulas and James, 2010)*** "Bushes"
	7. Small bushes, shrubs (20cm – 99cm high)	***(Wittig and Schreiber, 1983)*** "Hedges and shrubbery" ***(Young and Jarvis, 2001b)*** "Hedges and shrubbery" ***(Tzoulas and James, 2010)*** "Bushes"

		(Whitford et al., 2001) "Sub-shrubs" ***(Hermy and Cornelis, 2000)*** "Single tree or shrub not surrounded by other trees or shrubs"
	8. Climbing plants, vines	***(Wittig and Schreiber, 1983)*** "Wall communities" ***(Young and Jarvis, 2001a)*** "Wall communities"
	9. Creepers and ground covers (<10cm high)	***(Tzoulas and James, 2010)*** "Ground flora"
	10. Aquatic plants, reeds	***(Young and Jarvis, 2001b)*** "Reed communities; Communities of floating-leaf plants" ***(Tzoulas and James, 2010)*** "Aquatic" ***(Wittig and Schreiber, 1983)*** "Reed communities***;*** Communities of floating-leaf plants" ***(Hermy and Cornelis, 2000)*** "Tall herb vegetation: unit composed of rough herbs, inclusive reed vegetation"
	11. Tall grasses, forbs and herbs (>20cm)	***(Young and Jarvis, 2001b)*** "Areas of tall herbs/grasses" ***(Tzoulas and James, 2010)*** "High grasses and forbs" ***(Wittig and Schreiber, 1983)*** "Areas of tall herbaceous plants" ***(Young and Jarvis, 2001a)*** "Areas of tall herbs/grasses" (Fuller et al., 2007) "Unmown grassland" ***(Whitford et al., 2001)*** "Rough grass" ***(Freeman, 1999)*** "Grassland" ***(Hermy and Cornelis, 2000)*** "Tall herb vegetation: unit composed of rough herbs, inclusive reed vegetation"
	12. Low grasses, forbs and herbs (<20cm)	***(Young and Jarvis, 2001b)*** "Non-formal short grass area" ***(Tzoulas and James, 2010)*** "Low grasses and forbs" ***(Wittig and Schreiber, 1983)*** "Pasture***;*** Park grass/ornamental grass" ***(Fuller et al., 2007)*** "Mown grassland" ***(Whitford et al., 2001)*** "Turf grass"
	13. Mosses and lichens	***(Young and Jarvis, 2001b)*** "Moss/lichens/seedlings"
	14. Large rock/s (>50cm tall/wide)	Authors
	15. Bare soil; earth, clay, sand	***(Young and Jarvis, 2001b)*** "Bare areas" ***(Whitford et al., 2001)*** "Bare soil"
	16. Dead wood; logs, fallen trees	***(Young and Jarvis, 2001b)*** "Hollow trees of soft or dead wood" ***(Young and Jarvis, 2001a)*** "Dead wood"
	17. Detritus; leaf litter, mulch, bark	Authors
	18. Hardened/artificial surfaces; concrete, paving	***(Tzoulas and James, 2010)*** "Built" ***(Young and Jarvis, 2001b)*** "Paved area/pathway"

		(Fuller et al., 2007) "Impervious surface" ***(Whitford et al., 2001)*** "Asphalt/concrete"
	19. Semi-hardened surfaces; gravel, crushed rock, rubble	***(Wittig and Schreiber, 1983)*** "Semi (ruderal) xerothermic grassland (i.e. plants in waste or rubble)" ***(Young and Jarvis, 2001b)*** "Walls, broken stone or rubble" ***(Hermy and Cornelis, 2000)*** "Half-hardened: road with a hardening that is not completely sealed; half-hardened: path with a hardening that is not completely sealed"
	20. Artificial structure; fence, statue, bridge, monument, play equipment	***(Young and Jarvis, 2001b)*** "Artificial structure"
	21. Building with roof; gazebo, shelter	***(Tzoulas and James, 2010)*** "Built" ***(Whitford et al., 2001)*** "Buildings"
	22. Wall; retaining wall, building wall, brick wall	***(Young and Jarvis, 2001b)*** "Walls, broken stone or rubble" ***(Tzoulas and James, 2010)*** "Built" ***(Young and Jarvis, 2001a)*** "Walls, broken stone or rubble"
	23. Water bodies; ponds, lakes, pools, reservoirs, fountains	***(Young and Jarvis, 2001b)*** "Open water" ***(Young and Jarvis, 2001a)*** "Water feature (natural or artificial)" ***(Fuller et al., 2007)*** "Water" ***(Whitford et al., 2001)*** "Water" ***(Hermy and Cornelis, 2000)*** "Water feature: unit composed of water"
	24. Watercourses; creeks, streams, rivers, channels	***(Young and Jarvis, 2001b)*** "Open water" ***(Young and Jarvis, 2001a)*** "Water feature (natural or artificial)" ***(Fuller et al., 2007)*** "Water" ***(Whitford et al., 2001)*** "Water" ***(Hermy and Cornelis, 2000)*** "Watercourse: linear element used for the discharge of water"
	25. Dry creek or river bed	Authors
	26. Pronounced contours/slopes	***(Young and Jarvis, 2001b)*** "Pronounced contours" ***(Young and Jarvis, 2001a)*** "Pronounced contours"
	27. Cliffs/steep hills/gullies	***(Young and Jarvis, 2001b)*** "Pronounced contours" ***(Young and Jarvis, 2001a)*** "Pronounced contours"
Element Configurations	28. Tree row; distinct row or line of at least three trees	***(Young and Jarvis, 2001b)*** "Row(s) of trees" ***(Wittig and Schreiber, 1983)*** "Row(s) of trees" ***(Hermy and Cornelis, 2000)*** "Tree row: row of trees"
	29. Tree group; group of at least three trees planted	(Young and Jarvis, 2001b) "Group(s) of trees" ***(Wittig and Schreiber, 1983)*** "Group(s) of trees"

	closely together	
	30. Shrub row; distinct row or line of at least three shrubs, informal or formal hedge	***(Wittig and Schreiber, 1983)*** "Hedges and shrubbery" ***(Hermy and Cornelis, 2000)*** "Sheared hedge: hedge that is regularly sheared; non-sheared hedge: hedge that is not sheared" (Young and Jarvis, 2001b) "Hedges and shrubbery"
	31. Shrub group; group of at least three shrubs planted closely together	***(Young and Jarvis, 2001b)*** "Hedges and shrubbery" ***(Wittig and Schreiber, 1983)*** "Hedges and shrubbery" ***(Hermy and Cornelis, 2000)*** "Shrub plantation: unit composed of shrubs"

Appendix D The Habitat Types Checklist. This table outlines the 20 habitat types in the checklist, the studies from which they were derived, and the items they were adapted from.

An area must occupy at least 100m^2 [e.g. 10 x 10m] to be recorded as a habitat type.

Habitat Type	Description	Adapted/modified from
1. Mown grassland	Area of mown grass that is free of trees or shrubs (canopy cover excluded)	***(Freeman, 1999)*** "Playing fields" ***(Hermy and Cornelis, 2000)*** "Lawn; Sports field" ***(Pauleit and Duhme, 2000)*** "Sports fields" ***(Young and Jarvis, 2001a)*** "Park grass/ornamental lawn; Non-formal short grass area" ***(Freeman and Buck, 2003)*** "Grassland: pasture, tussock…exotic lawn…" ***(Honnay et al., 2003)*** "Grassland" ***(Fuller et al., 2007)*** "Mown grassland"
2. Unmown grassland	Area of unmown grass that is free of trees or shrubs (canopy cover excluded)	***(Freeman, 1999)*** "Grassland" ***(Hermy and Cornelis, 2000)*** "Hay meadow; Pasture; Hay-pasture" ***(Pauleit and Duhme, 2000)*** "Meadows and pastures; Extensive grasslands" ***(Young and Jarvis, 2001a)*** "Areas of tall herbs/grasses" ***(Freeman and Buck, 2003)*** "Grassland: pasture, tussock…exotic lawn…" ***(Honnay et al., 2003)*** "Grassland" ***(Simpson and Day, 2004)*** "Closed grassland; Tussock grassland; Hummock grassland" ***(Fuller et al., 2007)*** "Unmown grassland"
3. Open forest	Densely planted trees taller than 10m, without continuous canopy; understorey of shrubs and grasses. Refer to illustration*: tree canopies will overlap but allow light through in many places	***(Freeman and Buck, 2003)*** "Tree habitats: bush and forest…park/woodland" ***(Honnay et al., 2003)*** "Broad-leaved forest; Conifer forest; Mixed forest" ***(Simpson and Day, 2004)*** "Open forest"
4. Woodland	Relatively low density trees taller than 10m; ground cover grassy or shrubby. Refer to illustration*: average distance between tree crowns is more than ¼ of the average crown diameter.	***(Pauleit and Duhme, 2000)*** "Woodlands" ***(Young and Jarvis, 2001a)*** "Wood/wood-like parks" ***(Freeman and Buck, 2003)*** "Tree habitats: bush and forest…park/woodland" ***(Simpson and Day, 2004)*** "Woodland" ***(Fuller et al., 2007)*** "Woodland"
5. Low woodland	Relatively low density	***(Pauleit and Duhme, 2000)*** "Woodlands"

	trees shorter than 10m; ground cover grassy or shrubby	***(Freeman and Buck, 2003)*** "Tree habitats: bush and forest…park/woodland" ***(Simpson and Day, 2004)*** "Low woodland"
6. Open woodland	Sparsely planted trees taller than 10m, distance between tree crowns can be up to 20m	***(Pauleit and Duhme, 2000)*** "Woodlands" ***(Freeman and Buck, 2003)*** "Tree habitats: bush and forest…park/woodland" ***(Simpson and Day, 2004)*** "Open woodland"
7. Closed scrubland	Densely planted shrubs taller than 2m, with multiple stems at base, canopies overlapping	***(Freeman, 1999)*** "Scrub" ***(Hermy and Cornelis, 2000)*** "Shrub plantation: unit composed of shrubs" ***(Freeman and Buck, 2003)*** "Scrub habitats" ***(Simpson and Day, 2004)*** "Closed scrubland" ***(Fuller et al., 2007)*** "Scrub"
8. Open scrubland	Shrubs taller than 2, with multiple stems at base, canopies touching but not overlapping	***(Freeman, 1999)*** "Scrub" ***(Hermy and Cornelis, 2000)*** "Shrub plantation: unit composed of shrubs" ***(Freeman and Buck, 2003)*** "Scrub habitats" ***(Simpson and Day, 2004)*** "Open scrubland" ***(Fuller et al., 2007)*** "Scrub"
9. Tall shrubland	Relatively low density shrubs taller than 2m, with multiple stems at base, ground cover grassy or shrubby.	***(Freeman, 1999)*** Scrub" ***(Hermy and Cornelis, 2000)*** "Shrub plantation: unit composed of shrubs" ***(Freeman and Buck, 2003)*** "Shrubland" ***(Simpson and Day, 2004)*** "Tall shrubland" ***(Fuller et al., 2007)*** "Scrub"
10. Low shrubland	Well-separated shrubs up to 2m tall with multiple stems at base, ground cover grass or shrubby	***(Freeman, 1999)*** Scrub" ***(Hermy and Cornelis, 2000)*** "Heathland: unit composed of dwarfshrubs" ***(Freeman and Buck, 2003)*** "Shrubland" ***(Honnay et al., 2003)*** "Heath" ***(Simpson and Day, 2004)*** "Low shrubland" ***(Fuller et al., 2007)*** "Scrub"
11. Low open shrubland	Sparsely planted shrubs less than 1m tall with multiple stems at base, ground cover grassy or shrubby.	***(Freeman, 1999)*** "Scrub" ***(Hermy and Cornelis, 2000)*** "Heathland: unit composed of dwarfshrubs" ***(Freeman and Buck, 2003)*** "Shrubland" ***(Honnay et al., 2003)*** "Heath" ***(Simpson and Day, 2004)*** "Low open shrubland" ***(Fuller et al., 2007)*** "Scrub"
12. Scrub habitat	Area of densely planted trees with	***(Freeman, 1999)*** Scrub" ***(Hermy and Cornelis, 2000)*** "Shrub plantation: unit composed of

	relatively dense shrub/understory	shrubs" ***(Freeman and Buck, 2003)*** "Scrub habitats" ***(Fuller et al., 2007)*** "Scrub"
13. Shrubland	Area of relatively sparse trees, with relatively dense shrub/understory	***(Freeman, 1999)*** "Scrub" ***(Hermy and Cornelis, 2000)*** "Shrub plantation: unit composed of shrubs" ***(Freeman and Buck, 2003)*** "Shrubland" ***(Fuller et al., 2007)*** "Scrub"
14. Parkland	Area of grasses or low herbs, dotted with trees (low density)	***(Pauleit and Duhme, 2000)*** "Parks and green spaces" ***(Freeman and Buck, 2003)*** "Tree habitats: bush and forest…park/woodland"
15. Crops and horticultu re	Orchard, crops, vineyards, arable land	***(Hermy and Cornelis, 2000)*** "Orchard: enclosed unit planted with fruit trees"; "Agricultural area: unit composed of arable crops" ***(Whitford et al., 2001)*** "Vegetables, arable crops" ***(Freeman and Buck, 2003)*** "Crops and horticulture: orchard, vineyard…"
16. Edible garden	Vegetables and herbs, fruit trees, community garden	***(Hermy and Cornelis, 2000)*** "Kitchen garden: garden composed of vegetables and fruits"; "Herb garden: garden composed of medicinal herbs" ***(Whitford et al., 2001)*** "Vegetables, arable crops"
17. Amenity planting	Flower garden, rose garden, ornamental plants and flowers	***(Hermy and Cornelis, 2000)*** "Garden… composed of vegetables, fruit or ornamental plants"; "Ornamental garden: garden composed of other ornamental plants" ***(Whitford et al., 2001)*** "Flower beds" ***(Fuller et al., 2007)*** "Amenity planting"
18. Open water or wetland	Permanent or seasonal river, stream, waterfall, lake, pond, reservoir, pool or swamp.	***(Freeman, 1999)*** "Wetland" ***(Hermy and Cornelis, 2000)*** "Water feature: unit composed of water"; "Watercourse: linear element used for the discharge of water" ***(Pauleit and Duhme, 2000)*** "Lakes and ponds; Streams" ***(Young and Jarvis, 2001a)*** "Water feature (natural or artificial)" ***(Whitford et al., 2001)*** "Water" ***(Freeman and Buck, 2003)*** "Wetland; Open water" ***(Fuller et al., 2007)*** "Water"
19. Earth	Bare ground, soil, cliffs/rock outcrop, sand, gravel	***(Freeman, 1999)*** "Quarry" ***(Young and Jarvis, 2001a)*** "Bare areas" ***(Whitford et al., 2001)*** "Bare soil" ***(Freeman and Buck, 2003)*** "Bare ground/patchy vegetation" ***(Honnay et al., 2003)*** "Mud flat"
20. Built	Area dominated by buildings, artificial/impermeable	***(Hermy and Cornelis, 2000)*** "Building; Car park" ***(Whitford et al., 2001)*** "Buildings; asphalt/concrete"

	surfaces, walls, fences, bridges, statues, walls, monuments. Area at least 100m2, inclusive of limited space between objects (space less than 2m wide).	***(Freeman and Buck, 2003)*** "Built-up environment" ***(Honnay et al., 2003)*** "Built-up area; Infrastructure; Main road" ***(Tzoulas and James, 2010)*** "Built surfaces (includes roads)" ***(Fuller et al., 2007)*** "Impervious surface"

Appendix E The Anthropic Elements Checklist. This table outlines the 33 anthropic elements in the checklist, the studies from which they were derived, and the items they were adapted from.

Category	Anthropic Element	Adapted/modified from
Physical recreation	1. Soccer goals	***(Broomhall et al., 1996)*** "Soccer" ***(Lee et al., 2005)*** "Soccer field" [additional rating] ***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Soccer fields" [additional detail and ratings for condition, cleanliness, parking facilities, etc.] ***(Bedimo-Rung et al., 2006)*** "Soccer Fields" [additional detail about access, condition, lighting] ***(Kaczynski et al., 2012)*** "Sports Field (football/soccer)" [additional detail about condition]
	2. Football goals	***(Broomhall et al., 1996)*** "Football" ***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Football/rugby fields" [additional detail and ratings for condition, cleanliness, parking facilities, etc.] ***(Bedimo-Rung et al., 2006)*** "Football Fields" [additional detail about access, condition, lighting]
	3. Rugby goals	***(Broomhall et al., 1996)*** "Rugby" ***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Football/rugby fields" [additional detail and ratings for condition, cleanliness, parking facilities, etc.]
	4. Cricket pitch	***(Broomhall et al., 1996)*** "Cricket"
	5. Baseball diamond	***(Broomhall et al., 1996)*** "Baseball" ***Lee et al. (2005)*** "Baseball field" [additional rating] ***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Baseball/softball fields" [additional detail and ratings for condition, cleanliness, parking facilities, etc.] ***(Bedimo-Rung et al., 2006)*** "Baseball Fields" [additional detail about access, condition, lighting] ***(Kaczynski et al., 2012)*** "Baseball Field" [additional detail about condition]
	6. Batting cages	***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Batting cages" [additional detail and ratings for condition, cleanliness, parking facilities, etc.] ***(Bedimo-Rung et al., 2006)*** "Batting Cage/Warm Up Area" [additional detail about access, condition, lighting]
	7. Athletics track	***(Broomhall et al., 1996)*** "Athletics"

		(Saelens et al., 2006) "Athletic fields and other recreation areas… Athletic track" [additional detail and ratings for condition, cleanliness, parking facilities, etc.]
	8. BMX track	***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… BMX track" [additional detail and ratings for condition, cleanliness, parking facilities, etc.]
	9. Tennis courts	***(Broomhall et al., 1996)*** "Tennis" ***Lee et al. (2005)*** "Tennis courts" [additional rating] ***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Tennis courts" [additional detail and ratings for condition, cleanliness, parking facilities, etc.] ***(Bedimo-Rung et al., 2006)*** "Tennis Courts" ***(Kaczynski et al., 2012)*** "Tennis Court" [additional detail about condition]
	10. Basketball ring	***(Broomhall et al., 1996)*** "Basketball/Netball Hoops" ***(Lee et al., 2005)*** "Basketball courts" [additional rating] ***(Saelens et al., 2006)*** "Athletic fields and other recreation areas… Basketball courts" [additional detail and ratings for condition, cleanliness, parking facilities, etc.] ***(Bedimo-Rung et al., 2006)*** "Basketball Courts" ***(Kaczynski et al., 2012)*** "Basketball Court" [additional detail about condition]
	11. Netball ring	***(Broomhall et al., 1996)*** "Netball (grass/hard courts)"
	12. Children's playground	***(Broomhall et al., 1996)*** "Children's playground" [additional details about individual play equipment, shade, and type of playground surface] ***(Lee et al., 2005)*** "Play equipment" [additional rating] ***(Saelens et al., 2006)*** "Play set or structure features" [additional detail and ratings for color, features, equipment, ground surface, condition, cleanliness, etc.] ***(Bedimo-Rung et al., 2006)*** "Playgrounds" [additional detail about individual play equipment, playground surface, condition, fencing] ***(Kaczynski et al., 2012)*** "Playground" [additional details about condition, shade, seating]
	13. Table tennis table	Authors
	14. Lawn bowls	Authors
	15. Croquet	Authors
	16. Hockey	***(Broomhall et al., 1996)*** "Hockey"
	17. Walking trails	***(Broomhall et al., 1996)*** "Walking (only if paths)" [additional details about positioning of trails within park] ***(Lee et al., 2005)*** "Trails – running/biking" [additional rating] ***(Saelens et al., 2006)*** "Trails – Paved"; "Trails – Unpaved" [additional detail and ratings for surface, signage, seating, safety, comfort, etc.]

		(Bedimo-Rung et al., 2006) "Paths" [additional detail about width, slope, surface, condition] ***(Kaczynski et al., 2012)*** "Trail" [additional detail about condition, connectivity, distance]
	18. Designated cycle paths/ dual use paths	***(Broomhall et al., 1996)*** "Cycling" [additional details about positioning of trails within park]
	19. Exercise equipment/ stations	***(Broomhall et al., 1996)*** "Fitness Circuit" ***(Lee et al., 2005)*** "Exercise Stations" [additional rating] ***(Kaczynski et al., 2012)*** "Fitness Equipment/Stations" [additional detail about condition]
	20. Open lawn or field without designated use	***(Broomhall et al., 1996)*** "To what extent do you agree or disagree [that this] POS is suitable for casual ball sports." ***(Saelens et al., 2006)*** "Open space" [additional detail and ratings for size, condition, flatness, etc.] ***(Bedimo-Rung et al., 2006)*** "Green Spaces" ***(Kaczynski et al., 2012)*** "Open/Green Space" [additional detail about condition]
Passive recreation	21. Picnic tables	***(Broomhall et al., 1996)*** "Are picnic tables present?" ***(Lee et al., 2005)*** "Picnic tables shaded"; "Picnic tables no-shade" [additional rating] ***(Saelens et al., 2006)*** "Eating/drinking features… Picnic area" [additional detail and ratings for cleanliness, nearby facilities, etc.]; "Sitting or resting features (non-trail)… Tables" [additional detail and ratings for condition, cleanliness, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the shelters in the Target Area. What is located under the shelters? (e.g. Picnic Tables, Restroom, Grills, Drinking Fountain, Benches…" [additional detail about condition and cleanliness] ***(Kaczynski et al., 2012)*** "Are there picnic table(s) in the park?" [additional detail about condition]
	22. BBQs	***(Broomhall et al., 1996)*** "Are barbecues present?" ***(Saelens et al., 2006)*** "Eating/drinking features… Grills/fire pits" [additional detail and ratings for condition, cleanliness, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the shelters in the Target Area. What is located under the shelters? (e.g. Picnic Tables, Restroom, Grills, Drinking Fountain, Benches…"
	23. Benches/ seats	***(Broomhall et al., 1996)*** "Is there seating present?" ***(Lee et al., 2005)*** "Benches" [additional rating] ***(Saelens et al., 2006)*** "Sitting or resting features (non-trail)… Benches" [additional detail and ratings for condition, cleanliness, comfort, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all of the benches in the Target Area." [additional detail about condition] ***(Kaczynski et al., 2012)*** "Are there bench(es) to sit on in the park?" [additional detail about condition]

	24. Picnic shelter/ gazebo/ rotunda	***(Broomhall et al., 1996)*** "Gazebos/Rotunda" ***(Lee et al., 2005)*** "Shelters" [additional rating] ***(Saelens et al., 2006)*** "Facilities… Shelters/pavilions/gazebos" [additional detail and ratings for condition, cleanliness, features, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the shelters in the Target Area. What is located under the shelters? (e.g. Picnic Tables, Restroom, Grills, Drinking Fountain, Benches…"
	25. Dog park	***(Kaczynski et al., 2012)*** "Off-Leash Dog Park" [additional detail about condition]
	26. Lighting	***(Broomhall et al., 1996)*** "Is there lighting within the POS?" [additional details about positioning of lights within park] ***(Lee et al., 2005)*** "Lighting" [additional rating] ***(Bedimo-Rung et al., 2006)*** "Are there any light sources in the Target Area?" ***(Kaczynski et al., 2012)*** "Are there lights in the park? (not including neighborhood street lights" [additional detail about percentage of park lit]
	27. Restrooms/ toilets	***(Broomhall et al., 1996)*** "Are there public access toilets?" ***(Lee et al., 2005)*** "Bathrooms" [additional rating] ***(Saelens et al., 2006)*** "Facilities… Restrooms" [additional detail and ratings for condition, cleanliness, accessibility, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the shelters in the Target Area. What is located under the shelters? (e.g. Picnic Tables, Restroom, Grills, Drinking Fountain, Benches…" [additional detail about gender-labels, locking, functionality, cleanliness] ***(Kaczynski et al., 2012)*** "Are there public restroom(s) or portable toilet(s) at the park?" [additional detail about condition]
	28. Water bubbler/ drinking fountain	***(Broomhall et al., 1996)*** "Are drinking fountains present?" ***(Lee et al., 2005)*** "Drinking fountain" [additional rating] ***(Saelens et al., 2006)*** "Eating/drinking features… Drinking water fountains" [additional detail and ratings for condition, accessibility, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the shelters in the Target Area. What is located under the shelters? (e.g. Picnic Tables, Restroom, Grills, Drinking Fountain, Benches…" [additional detail about functionality and cleanliness] ***(Kaczynski et al., 2012)*** "Are there drinking fountain(s) at the park?" [additional detail about number of fountains and condition]
	29. Kiosk or café	***(Broomhall et al., 1996)*** "Is there a kiosk/café present?" [additional details about opening times] ***(Saelens et al., 2006)*** "Eating/drinking features… Vending" [additional detail and ratings for affordability, operation, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the concession stands in the Target Area. What can you buy at the concession stand? (e.g. Drink, Food…)" ***(Kaczynski et al., 2012)*** "Is there food/vending machines available in the park?" [additional detail about fruit and vegetables]

Aesthetics	30. Bridge	***(Broomhall et al., 1996)*** "Bridge"
	31. Statue or monument	***(Broomhall et al., 1996)*** "Statues" ***(Saelens et al., 2006)*** "Education/historical features… Historical markers or monuments" [additional detail and ratings for condition, cleanliness, lighting, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the art or monuments in the Target Area." [additional detail about condition] ***(Kaczynski et al., 2012)*** "Artistic feature (e.g. statue, sculpture, gazebo, fountain)"
	32. Sculpture or art	***(Broomhall et al., 1996)*** "Sculptures" ***(Saelens et al., 2006)*** "General aesthetics… Sculpture or other art" [additional detail and ratings for content, signage, etc.] ***(Kaczynski et al., 2012)*** "Artistic feature (e.g. statue, sculpture, gazebo, fountain)"
	33. Water feature	***(Broomhall et al., 1996)*** "Type of water feature: Lake, Pond, Water Fountain, Stream" ***(Lee et al., 2005)*** "Fountains" [additional rating] ***(Saelens et al., 2006)*** "Water areas… Fountains" [additional detail and ratings for size, condition, aesthetics, etc.] ***(Bedimo-Rung et al., 2006)*** "Locate all the water features in the Target Area. What type of water feature is it? (e.g. Pond/lagoon, Lake… Built Fountain…" ***(Kaczynski et al., 2012)*** "Artistic feature (e.g. statue, sculpture, gazebo, fountain)"

Appendix F The questionnaire distributed to the residents of Burnside, Mitcham and Unley Councils

The Nature of Health

University of South Australia

beyondblue

Nature FOUNDATION SA

The Nature of Health

Welcome

We would love you to participate in our study, The Nature of Health. This survey should take about 15 minutes to complete. **As a sign of our appreciation, and in keeping with the spirit of this research, the Nature of Health will donate $100 for every 50 people who complete this survey to both '*beyondblue*' (www.beyondblue.org.au) and 'Nature Foundation SA' (www.naturefoundation.org.au)**, two not-for-profit organisations working to improve Australia's health and protect South Australia's natural environment, respectively.

You might be surprised to learn that people living in cities, like you and I, face a much higher risk of developing a mental illness such as anxiety, depression, or schizophrenia than people living in rural areas. Unfortunately, in any given year, millions of Australians suffer from poor mental health, and a staggering 45% of the population will experience a mental illness in their lifetime. We are investigating the potential benefits of nature on people's wellbeing, and in doing so, seek to generate support for both human and environmental health. To succeed at this, we need your help.



For the purpose of this study we are defining "green spaces" as public parks, reserves, and other natural areas. We appreciate these spaces are not always green, but hope that using one generic term will help to simplify the survey.
Your contribution is important to us and we thank you in advance for your help. Further detail about this survey is available at the back of this booklet.

Once you have completed this survey, please place it in the reply-paid envelope, and post it back to us. There is no need to return the map.

If you would prefer to complete this survey online, or another member of your household would also like to do the survey, please visit: **www.natureofhealth.org**

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Park use

1. In general, which one of the following types of green space would you prefer to visit? (i.e. if distance, available time, or family responsibilities were not an issue).

○	**Sports fields, school ovals, sporting facilities or playgrounds**	i.e. green spaces where the primary focus is sport, e.g. football fields, tennis courts, bowling greens.
○	**Community parks or reserves**	i.e. green spaces that have a variety of recreational facilities, such as picnic areas, exercise equipment and playgrounds, but also natural/vegetated areas, e.g. Ridge Park, Orphanage Park, Mitcham Reserve, CC Hood, Hazelwood Park, Kensington Gardens Reserve.
○	**Nature reserves or conservation parks**	i.e. predominantly vegetated areas set aside for conservation, e.g. Belair National Park, Cleland Conservation Park, Waterfall Gully Reserve.
○	**I would prefer not to visit green spaces**	
○	**Any/all types of green spaces**	

2. In general, how frequently do you visit green spaces?

Daily	Weekly	Fortnightly	Monthly	Every few months	Yearly	Rarely
○	○	○	○	○	○	○

3. Please estimate the number of green spaces that exist within a 10 minute walk from your home (i.e. within about 800 metres).

[ ]

4. How would you describe the mix of green spaces in your local area (within a 10 minute walk/about 800 metres from home)?

- O **Lots** of green spaces, but all **quite similar types** (e.g. mostly sports ovals, or mostly playgrounds)
- O **Lots** of green spaces, of a **variety of different types** (e.g. sports ovals, community parks, nature reserves, linear parks)
- O **Few** green spaces of **quite similar types**
- O **Few** green spaces, but **some different types**
- O N/A - no green spaces within a 10 minute walk from home

5. On the scale below, how would you rate the overall quality of the green spaces within a 10 minute walk from home?

1 Very low quality	2	3	4	5	6	7	8	9	10 Exceptional quality
○	○	○	○	○	○	○	○	○	○

6. How would you rate your understanding of 'biodiversity'?

1 Very low level of understanding	2	3	4	5	6	7	8	9	10 Very high level of understanding
○	○	○	○	○	○	○	○	○	○

7. Have you had any formal training in biodiversity conservation as a part of your education, employment, or volunteering?

O Yes O No O Unsure

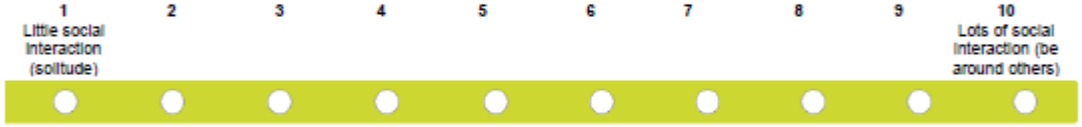
8. If I could choose, I'd want my local parks to be...



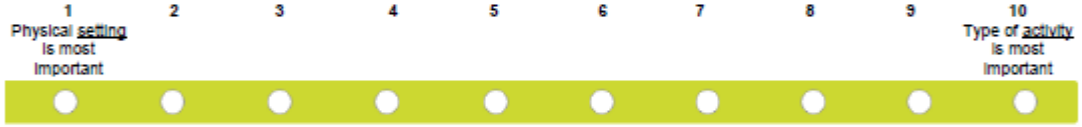
9. I prefer to spend time in settings that are...



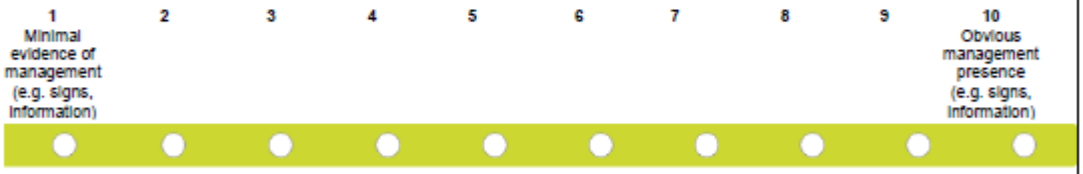
10. I prefer to spend time in environments that provide...



11. When choosing to visit a green space...



12. I like green spaces to show...



13. The following items are attributes of parks that South Australians have expressed a love of. Please rank them in order of importance to you, with 1 being the most important 'ingredient' in the parks you like to visit, and 6 being the least important.

	Walking and cycling trails
	The sounds and smells of nature
	Proximity to home
	Plants and trees
	Maintenance and cleanliness
	Birds and wildlife

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NOTE: Please refer to the labelled map of green spaces to answer the following questions.

14. Using the map, please identify four green spaces that you visit (select only parks with yellow labels, even if your favourite parks are not included in the list). Please write the park names here:

Note: You can also find a list of parks on the back page of the survey.

Park A	
Park B	
Park C	
Park D	

15. How often do you visit each of these parks?

Park A		times per	**Week**	**Month**	**Year**	(please circle one)
Park B		times per	**Week**	**Month**	**Year**	(please circle one)
Park C		times per	**Week**	**Month**	**Year**	(please circle one)
Park D		times per	**Week**	**Month**	**Year**	(please circle one)

16. How would you rate the level of physical benefit you derive from a typical visit to each of these parks? (i.e. from being physically active).

	1 Very low level of physical benefit	2	3	4	5	6	7 Very high level of physical benefit
Park A	○	○	○	○	○	○	○
Park B	○	○	○	○	○	○	○
Park C	○	○	○	○	○	○	○
Park D	○	○	○	○	○	○	○

17. What would you say is the main benefit you derive from a typical visit to each of these parks? (Please select one benefit per park).

	Enjoy scenery	Mentally unwind, escape everyday pressures	Escape crowds, enjoy solitude	Spend time with friends/family	Improve or maintain fitness	Physically rest/relax	Learn about nature	Other
Park A	○	○	○	○	○	○	○	○
Park B	○	○	○	○	○	○	○	○
Park C	○	○	○	○	○	○	○	○
Park D	○	○	○	○	○	○	○	○

18. How would you describe the overall level of plant and animal diversity in each of these parks?

	1 Very low level of diversity	2	3	4	5	6	7 Very high level of diversity
Park A	○	○	○	○	○	○	○
Park B	○	○	○	○	○	○	○
Park C	○	○	○	○	○	○	○
Park D	○	○	○	○	○	○	○

19. How would you rate the scenic beauty of each of these parks?

	1 Very unattractive	2	3	4 Neither attractive nor unattractive	5	6	7 Very attractive
Park A	○	○	○	○	○	○	○
Park B	○	○	○	○	○	○	○
Park C	○	○	○	○	○	○	○
Park D	○	○	○	○	○	○	○

20. How would you rate the 'naturalness' of each park on the scale below?

	1 100% artificial and/or urban	2	3	4 50% artificial, 50% natural	5	6	7 100% natural
Park A	○	○	○	○	○	○	○
Park B	○	○	○	○	○	○	○
Park C	○	○	○	○	○	○	○
Park D	○	○	○	○	○	○	○

21. How would you describe the amount of natural shade at each of these parks? (i.e. from trees).

	1 Very little or no natural shade	2	3	4	5	6	7 Lots of natural shade, very shady
Park A	○	○	○	○	○	○	○
Park B	○	○	○	○	○	○	○
Park C	○	○	○	○	○	○	○
Park D	○	○	○	○	○	○	○

22. How do you think a typical visit to each of these green spaces would improve the following aspects of your wellbeing? Please indicate the strength of the effect, by writing a number in each of the boxes below, with 1 being 'a very small improvement' and 10 being 'a very big improvement'. If you feel that visiting a particular green space would have no effect on you (or make you feel worse), please write '0'.

	My stress level 0 = no change, 1 = very small improvement, 10 = very big improvement	My mood 0 = no change, 1 = very small improvement, 10 = very big improvement	My concentration 0 = no change, 1 = very small improvement, 10 = very big improvement	My self-esteem 0 = no change, 1 = very small improvement, 10 = very big improvement
Park A				
Park B				
Park C				
Park D				

23. Please rate the extent to which you agree with each of the following statements. Please respond as you really feel, rather than how you think "most people" feel.

	Agree strongly	Agree a little	Neither agree nor disagree	Disagree a little	Strongly disagree
I enjoy being outdoors, even in unpleasant weather	○	○	○	○	○
Some species are just meant to die out or become extinct	○	○	○	○	○
Humans have the right to use natural resources any way we want	○	○	○	○	○
My ideal vacation spot would be a remote, wilderness area	○	○	○	○	○
I always think about how my actions affect the environment	○	○	○	○	○
I enjoy digging in the earth and getting dirt on my hands	○	○	○	○	○
My connection to nature and the environment is a part of my spirituality	○	○	○	○	○
I am very aware of environmental issues	○	○	○	○	○
I take notice of wildlife wherever I am	○	○	○	○	○
I don't often go out in nature	○	○	○	○	○
Nothing I do will change problems in other places on the planet	○	○	○	○	○
I am not separate from nature, but a part of nature	○	○	○	○	○
The thought of being deep in the bush, away from civilisation, is frightening	○	○	○	○	○
My feelings about nature do not affect how I live my life	○	○	○	○	○
Animals, birds, and plants should have fewer rights than humans	○	○	○	○	○
Even in the middle of the city, I notice nature around me	○	○	○	○	○
My relationship to nature is an important part of who I am	○	○	○	○	○
Conservation is unnecessary because nature is strong enough to recover from any human impact	○	○	○	○	○
The state of non-human species is an indicator of the future for humans	○	○	○	○	○
I think a lot about the suffering of animals	○	○	○	○	○
I feel very connected to all living things and the earth	○	○	○	○	○

24. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
○	○	○	○	○

25. The following items are about activities you might do during a typical day.

	Yes, limited a lot	Yes, limited a little	No, not at all
Does your health limit you in undertaking moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf?	○	○	○
What about climbing several flights of stairs? Does your health limit you?	○	○	○

26. During the past four weeks:

	Yes	No
During the past four weeks, have you accomplished less than you would like with your work or other regular daily activities as a result of your physical health?	○	○
During the past four weeks, were you limited in the kind of work or other activities as a result of your physical health?	○	○
During the past four weeks, have you accomplished less than you would like with your work or other regular daily activities as a result of any emotional problems, such as feeling depressed or anxious?	○	○
During the past four weeks, did you not do work or other activities as carefully as usual as a result of any emotional problems, such as feeling depressed or anxious?	○	○

27. During the past four weeks, how much did pain interfere with your normal work, including both work outside the home and housework?

Not at all	A little bit	Moderately	Quite a bit	Extremely
○	○	○	○	○

28. The following questions are about how you feel and how things have been with you during the past four weeks. Please give the answer that comes closest to the way you have been feeling.

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
How much of the time during the past four weeks have you felt calm and peaceful?	○	○	○	○	○	○
How much of the time during the past four weeks did you have a lot of energy?	○	○	○	○	○	○
How much of the time during the past four weeks have you felt downhearted and blue (or down)?	○	○	○	○	○	○
How much of the time during the past four weeks has your physical health or emotional problems interfered with your social activities like visiting friends or relatives?	○	○	○	○	○	○

29. Please read each statement and select the answer that indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

	Almost always	Often	Sometimes	Never
I found it hard to wind down	○	○	○	○
I couldn't seem to experience any positive feeling at all	○	○	○	○
I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion)	○	○	○	○
I found it difficult to work up the initiative to do things	○	○	○	○
I tended to over-react to situations	○	○	○	○
I experienced trembling (e.g. in the hands)	○	○	○	○
I was aware of dryness of my mouth	○	○	○	○
I felt that I was using a lot of nervous energy	○	○	○	○
I was worried about situations in which I might panic and make a fool of myself	○	○	○	○
I felt that I had nothing to look forward to	○	○	○	○
I found myself getting agitated	○	○	○	○
I found it difficult to relax	○	○	○	○
I felt down-hearted and blue	○	○	○	○
I was intolerant of anything that kept me from getting on with what I was doing	○	○	○	○
I felt I was close to panic	○	○	○	○
I was unable to become enthusiastic about anything	○	○	○	○
I felt I wasn't worth much as a person	○	○	○	○
I felt that I was rather touchy	○	○	○	○
I was aware of the action of my heart in the absence of physical exertion (e.g. sense of heart rate increase, heart missing a beat)	○	○	○	○
I felt scared without any good reason	○	○	○	○
I felt that life was meaningless	○	○	○	○

30. What is your gender?

○ **Male** ○ **Female**

31. In which year were you born? _____

32. In which Council area do you reside? _____

33. How important do you think biodiversity is to the health and wellbeing of you and your family?

Highly important	Fairly important	Neither important nor unimportant	Fairly unimportant	Highly unimportant	I don't know what biodiversity is
○	○	○	○	○	○

34. Looking at the words and concepts listed below, please select each item that you would feel confident explaining the meaning of to another person:

- ○ Biodiversity
- ○ Ecosystem
- ○ Keystone species
- ○ Ecosystem services
- ○ Natural capital
- ○ Habitat fragmentation
- ○ Endemic species
- ○ Remnant vegetation
- ○ Island biogeography
- ○ Biodiversity hotspot
- ○ Umbrella species
- ○ Edge effect
- ○ I would not feel confident explaining any of these concepts to another person

35. In my opinion, the possible consequences of biodiversity loss include:

- ○ Reduced food security
- ○ Substantial ozone depletion
- ○ Destruction of potential pharmaceuticals
- ○ Pollution
- ○ Increased spread of infectious diseases
- ○ Rapid human population growth
- ○ Increased frequency of natural disasters
- ○ I don't know

36. What is your current employment status?

- ○ Working and/or studying full time
- ○ Working or studying part time
- ○ Unemployed/looking for work
- ○ At-home duties
- ○ Retired
- ○ Prefer not to say

37. Approximately how many hours per week do you engage in paid work? _____

38. What is the highest level of formal education you have completed?

- ○ Year 11 or below
- ○ Year 12
- ○ Technical or trade qualification
- ○ Bachelor degree
- ○ Postgraduate degree (Masters or higher)
- ○ Prefer not to say

39. Which of the following options best describes your household?

- ○ Sole adult (regardless of relationship status)
- ○ Adult housemates
- ○ Couple, no children at home
- ○ Young family (youngest child 6 years or younger)
- ○ Middle family (youngest child 7-18 years)
- ○ Mature family (youngest child over 18 years)

40. What is your marital status?

- ○ Single, never married
- ○ Married/ De Facto/ Domestic Partnership
- ○ Widowed
- ○ Separated
- ○ Divorced
- ○ Prefer not to say

The Nature of Health

This completes the questionnaire. Thank you for your participation! If you would like to receive a summary of the results, please enter your email address below. Estimated completion of the study is December 2015.

Consent information

You should be 18 years of age or older to participate in this survey. This project has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant please contact the Executive Officer of this Committee, Tel: +61 8 8302 3118; Email: Vicki.allen@unisa.edu.au

Purpose of Research

The University of South Australia is conducting this research project to gather information about South Australians' use of green spaces. The results of this research are intended to assist planners and park managers to make informed decisions about protecting and improving the management of green spaces, now and into the future.

Risks and Benefits

We do not foresee any risks in participating in this study. A potential benefit for you is to have your preferences recognized and used in future park management decisions. By participating in this study, you are also contributing to the financial support of *beyondblue* and the *Nature Foundation of South Australia*, as the University of South Australia will make a donation on behalf of each person who returns a completed survey.

Participation and Withdrawal

Your participation is entirely voluntary. You may withdraw from the study at any point, without consequences of any kind.

Data Collection, Storage and Use

This survey is being administered on a secure computer server. The responses you submit will be stored in a secure database that contains every response we receive (located in P2-18, Mawson Lakes Campus of University of South Australia). Your responses will not be personally identifiable in this database. The data will be summarized and published in a report. The researcher will take every care to remove responses from any identifying material as early as possible. Likewise individual responses will be kept confidential by the researcher and not be identified in the reporting of the research. Non-identifiable data will be retained for five years.

Reporting Findings

All records containing personal information will remain confidential and no information which could lead to identification of any individual will be released unless required by law. A summary of the research findings can be emailed to you at the completion of the study (expected date of completion is December 10, 2015) if you desire and you choose to provide an email address for this purpose.

Contact Information

If you have any questions or concerns about this research, please feel free to contact us:

Assoc. Professor Delene Weber (delene.weber@unisa.edu.au)
Morgan Schebella (morgan.schebella@unisa.edu.au; phone: 08 8302 3766)
University of South Australia

List of parks shown on map (A-Z)

PARK NAME	COUNCIL AREA	PARK NAME	COUNCIL AREA
AA Bailey Reserve	MITCHAM	Knofel Park	MITCHAM
Alan E Cousin Reserve	BURNSIDE	Langman Recreation Reserve	BURNSIDE
Alexandra Avenue Plantation	BURNSIDE	Light Place Reserve	MITCHAM
Alma Avenue Reserve	MITCHAM	Ludgate Circus Reserve	MITCHAM
Attunga Gardens	BURNSIDE	Marschall Boulevard Reserve	MITCHAM
Austral Park	BURNSIDE	Mellor Reserve	BURNSIDE
Avenue Road Reserve	MITCHAM	Michael Perry Botanic Reserve	BURNSIDE
Balham Reserve	MITCHAM	Miller Reserve	BURNSIDE
Batchelor Reserve	MITCHAM	Mitcham Reserve	MITCHAM
Beaumont Common	BURNSIDE	Mortlock Park	MITCHAM
Belair National Park	MITCHAM	Mount Osmond Reserve	BURNSIDE
Bell Yett Reserve	BURNSIDE	Naomi Reserve	MITCHAM
Birksgate Drive Reserve	MITCHAM	Netherby Reserve	MITCHAM
Blackwood Hill Reserve	MITCHAM	Newland Park	BURNSIDE
Bligh Avenue Reserve	MITCHAM	North Unley Playpark	UNLEY
Branson Reserve	BURNSIDE	Oakdene Road Reserve	MITCHAM
Branson Reserve	MITCHAM	Orphanage Park	UNLEY
Brock Reserve	BURNSIDE	Oxford Circus Reserve	MITCHAM
Brownhill Creek Reserve	MITCHAM	Page Park	UNLEY
CC Hood Reserve	MITCHAM	Pasadena Reserve	MITCHAM
Chambers Gully Reserve	BURNSIDE	Penfold Park	BURNSIDE
Chapel Street Reserve	BURNSIDE	Philips Reserve	BURNSIDE
Chellaston Reserve	MITCHAM	Piazza Reserve	MITCHAM
Civic Centre Gardens	BURNSIDE	Plane Tree Reserve	BURNSIDE
Clapham Reserve	MITCHAM	Prescott Terrace Plantation	BURNSIDE
Cleland Conservation Park	BURNSIDE	Price Memorial Oval	MITCHAM
Constable Hyde Memorial Garden	BURNSIDE	Ragless Reserve	MITCHAM
Denman Reserve	MITCHAM	Railway Precinct & Nellie's Garden	MITCHAM
Donald Street Reserve	MITCHAM	Randell Park	MITCHAM
Eagle Park	MITCHAM	Ray Cooper Gardens	BURNSIDE
Effie Ferguson Reserve	BURNSIDE	Reade Park Reserve	MITCHAM
Eliza Place Reserve	MITCHAM	Ridge Park	UNLEY
Elizabeth Reserve	BURNSIDE	Ritz Boulevard Reserve	MITCHAM
Ferguson Avenue Reserve	UNLEY	Riverside Reserve	MITCHAM
Ferguson Conservation Park	BURNSIDE	Rozelle Reserve	MITCHAM
Fergusson Square	BURNSIDE	Saddle Hill Reserve	MITCHAM
Forest Avenue Reserve	UNLEY	Scammell Reserve	UNLEY
Forestville Reserve	UNLEY	Shepherds Hill Recreation Park	MITCHAM
Francis Reserve	MITCHAM	Sierra Nevada Reserve	MITCHAM
Fraser Reserve	UNLEY	Simpson Parade Reserve	UNLEY
Frome Reserve	MITCHAM	Simpson Reserve	BURNSIDE
Fullarton Park	UNLEY	Sleeps Hill Reserve	MITCHAM
Glenside Detention Basin	BURNSIDE	Soldiers Memorial Gardens	MITCHAM
Glenunga Reserve	BURNSIDE	Soldiers Memorial Gardens	UNLEY
Godden Reserve	MITCHAM	Soutar Park	UNLEY
Goodwood Oval	UNLEY	St. Marys Close	MITCHAM
Grant Jacob Reserve	MITCHAM	St. Marys Park & Norman St. Reserve	MITCHAM
Gully Reserve	BURNSIDE	St. Marys Reserve	MITCHAM
Gully Reserve	MITCHAM	Sturt Gorge Recreation Park	MITCHAM
Harris Reserve	BURNSIDE	Symons & Symons Reserve	BURNSIDE
Harvey Hayes Reserve	MITCHAM	Thistleton Reserve	MITCHAM
Hazelwood Park	BURNSIDE	Thurles Street Reserve	MITCHAM
Henry Martin Square	BURNSIDE	Tregenza Oval	BURNSIDE
Heywood Park	UNLEY	Tusmore Park	BURNSIDE
Hillview Reserve	MITCHAM	Unley Oval	UNLEY
Holmes Reserve	BURNSIDE	WA Norman Baseball Reserve	MITCHAM
Howard Florey Reserve	UNLEY	Waite Arboretum	MITCHAM
Hubbe Court Reserve	BURNSIDE	Waite Oval	MITCHAM
Ifould Reserve	BURNSIDE	Warland Reserve	BURNSIDE
JB Ware Reserve	BURNSIDE	Waterfall Gully Reserve	BURNSIDE
Kegworth Reserve	MITCHAM	Waterfall Terrace Reserve	BURNSIDE
Kensington Gardens Reserve	BURNSIDE	Watiparinga Reserve	MITCHAM
Kensington Park Reserve	BURNSIDE	Webb Street Reserve	BURNSIDE
Kent Road Reserve	MITCHAM	Willowbridge Reserve	BURNSIDE
Kentucky Reserve	MITCHAM	Windsor Street Linear Reserve	UNLEY
Kingsley Avenue Reserve	BURNSIDE	Wittunga Botanical Gardens	MITCHAM
Kingswood Oval	MITCHAM	Wood Park	BURNSIDE

Appendix G Postcard invitation delivered to 150 households as part of the pilot study

Front



Back

www.natureofhealth.org

Dear resident,

Please help us by participating in an online survey.

Unfortunately, in any given year, millions of Australians suffer from anxiety or depression, and a staggering 45% of the population will experience a mental health issue in their lifetime. We are investigating the potential benefits of nature on people's wellbeing, and in doing so, seek to generate support for both human and environmental health. To succeed at this, we need your help.

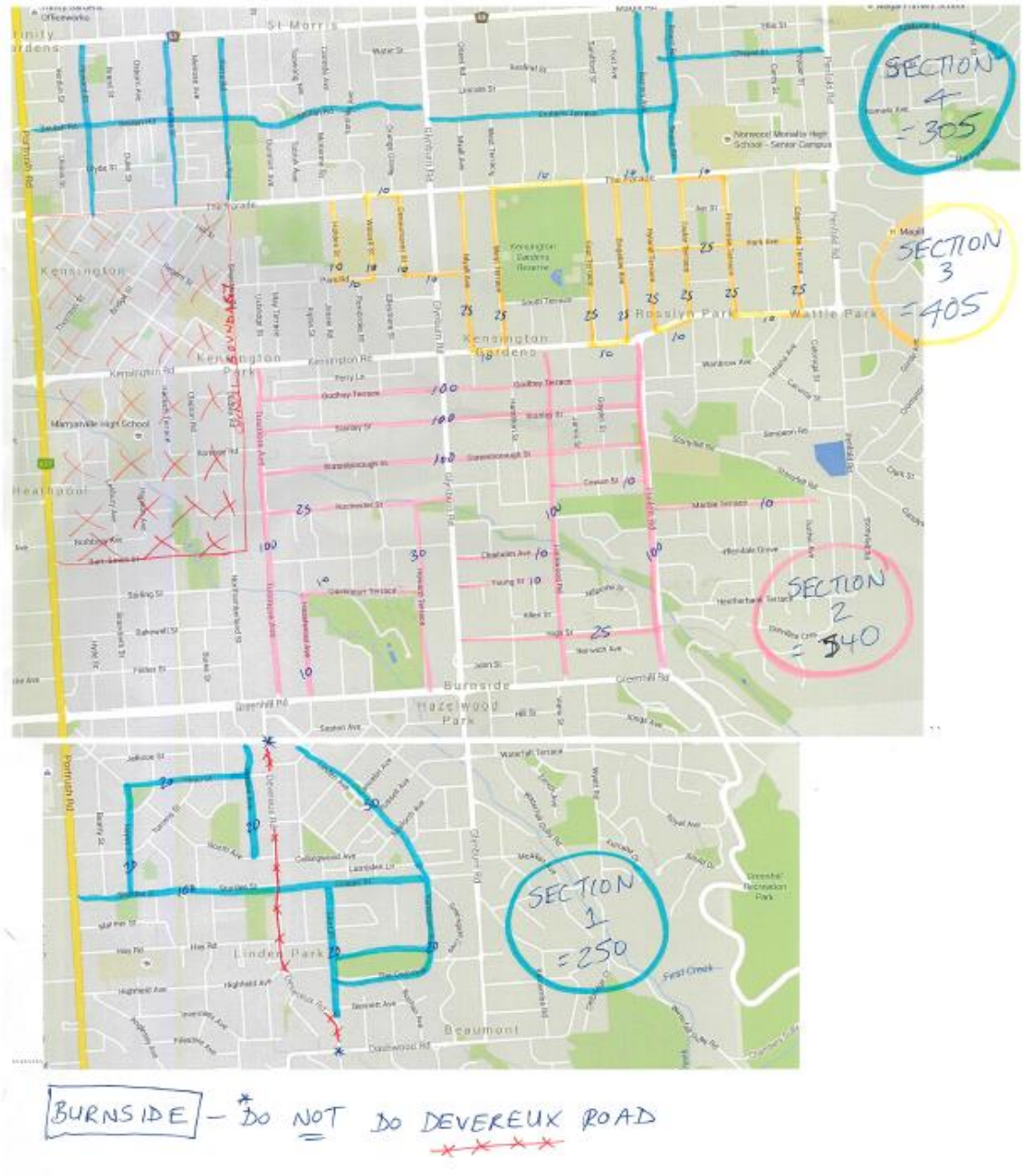
Your participation in this survey is greatly appreciated. **As a sign of our appreciation, and in keeping with the spirit of this research, the Nature of Health will donate $100 for every 50 people who complete this survey to both '*beyondblue*' (www.beyondblue.org.au) and 'Nature Foundation SA' (www.naturefoundation.org.au)**, two not-for-profit organisations working to improve Australia's health and protect South Australia's natural environment, respectively.

The Nature of Health | University of South Australia | beyondblue | Nature FOUNDATION SA

This project has been approved by the University of South Australia's Human Research Ethics Committee (protocol #0000032708). The information you provide is confidential and will not be individually identifiable. If you have any questions about this study, please contact Assoc. Prof. Delene Weber (delene.weber@unisa.edu.au) or Morgan Schebella (morgan.schebella@unisa.edu.au).

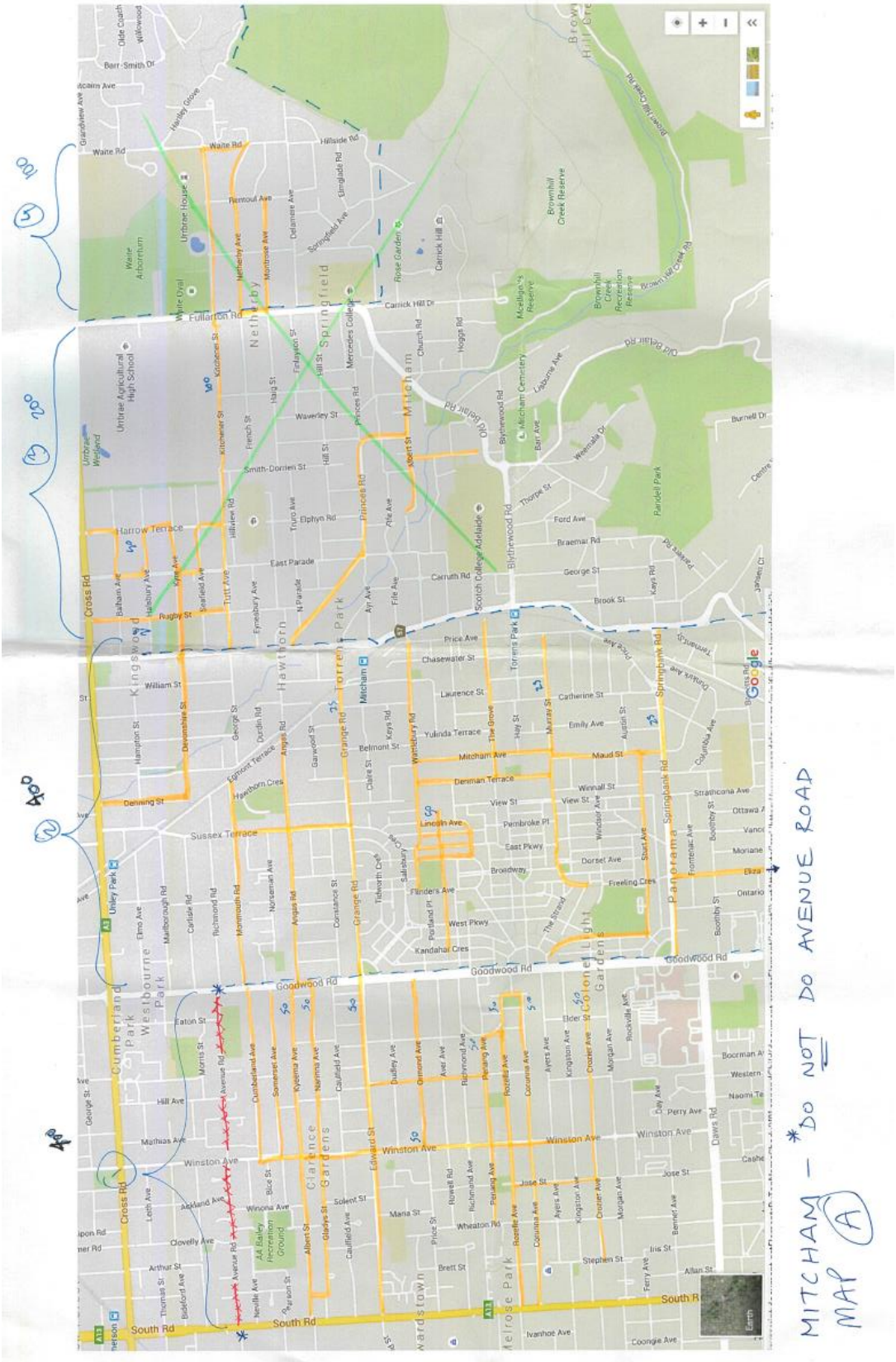
Appendix H Zones for delivery of questionnaires across the three Council areas

Burnside delivery zones

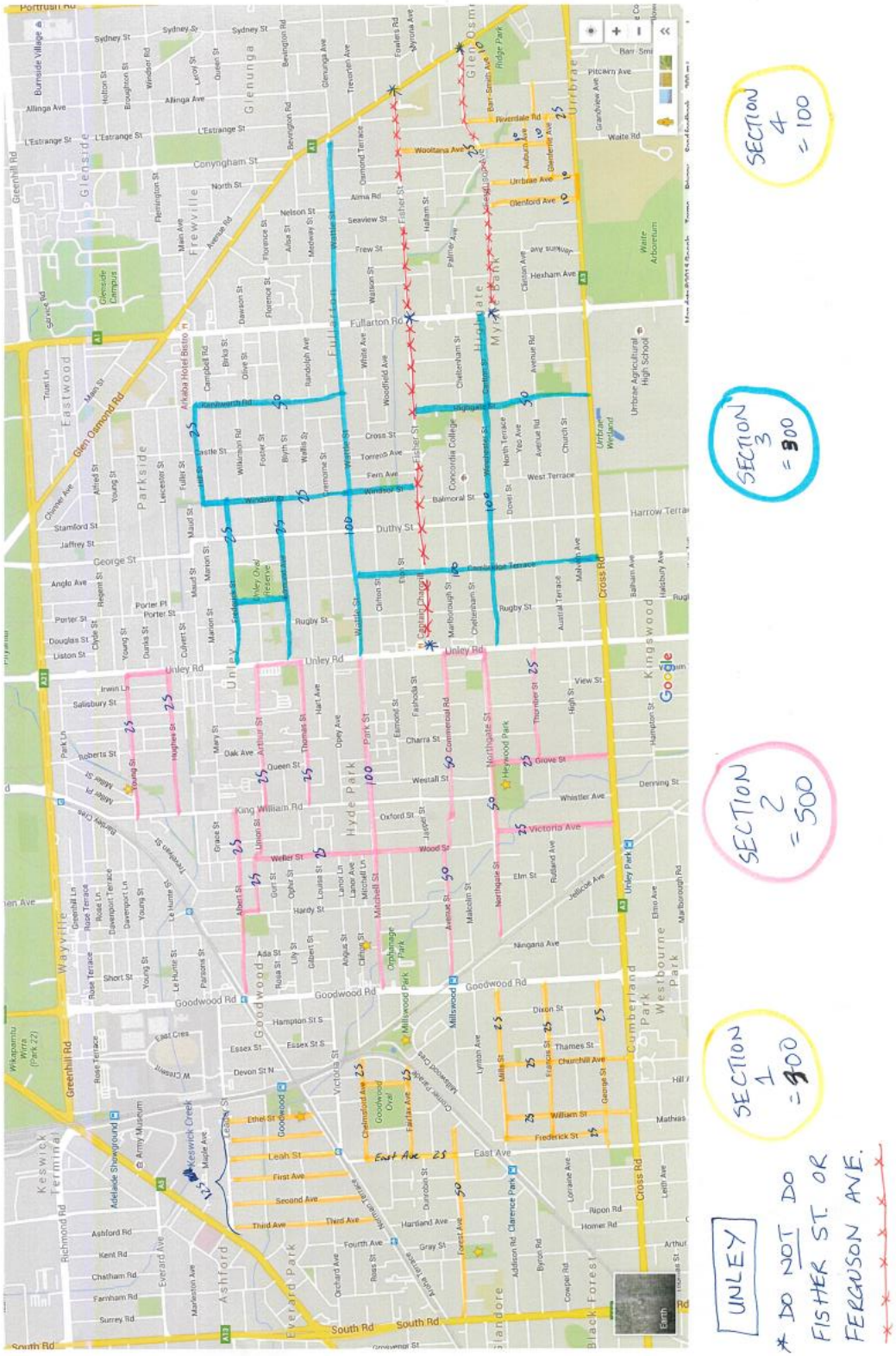


Mitcham delivery

zones



Unley delivery zones



Appendix I Screening questionnaire for the IVE experiment

Pre-experiment Questionnaire

Thank you for your willingness to participate in the 'virtual reality' experiment!

Providing you with the following information will help us to ensure everything runs smoothly during your experience. You will be given more detail about the experiment procedure on the day of the experiment, but for now, the most important things to know are:

- The experiment will take place in P2-53 at UniSA's Mawson Lakes Campus, between July 25 and August 5. You can find a campus map here. Please call 04483 87002 if you get lost).
- It will take approximately 40 minutes to complete the experiment.
- During the experiment you will wear headphones and a virtual reality headset, so please don't wear large earrings or a hairstyle that might make this equipment uncomfortable for you (e.g. ponytail).
- Due to the use of virtual reality headsets, we cannot allow you to participate in the experiment if you have epilepsy, a heart condition, or a blood pressure issue that requires medication.
- The next page is a formal consent form. By completing this pre-experiment questionnaire, you are consenting that you understand the process outlined on the next page.



Pre-experiment Questionnaire

Informed Consent Form for Experimental Participants

Please read the following information carefully. You may also request a copy for future reference.
This study has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant, please contact the Executive Officer of this Committee, Tel: +61 8 8302 3118; Email: Vicki.allen@unisa.edu.au

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Experiment: Human responses to 'virtual reality' environments
Investigators: Morgan Schebella, Associate Professor Delene Weber, and Professor Philip Weinstein
Affiliation: The University of South Australia

DESCRIPTION: You are invited to participate in a research study that investigates the effects of different 'virtual reality' environments on the human relaxation response. During the experiment, you will be asked to wear a virtual reality headset (similar to a large pair of goggles), and a wristband with built in skin sensors that measures how relaxed you are. You will be presented with a task to complete, which may increase your heart rate. You will be asked to complete a short questionnaire several times during the experiment.

PURPOSE: The purpose of this study is to gain an understanding of how people respond physically and mentally to different environments. The information collected during this project will help to guide the design of healthy and sustainable communities.

RISKS AND BENEFITS: There is little potential risk involved with this study. During some stages, you may feel less relaxed and your heart rate may be slightly elevated, but no more so than during various day-to-day activities. There are no direct benefits to participation, however, you may enjoy experiencing 'virtual reality' technology and contributing to research that aims to improve the lives of urban inhabitants. Upon completion of the study (November 2016) you may also request a copy of the results by emailing the researchers.

TIME INVOLVEMENT: Your participation in the experiment will take approximately 40 minutes.

DATA SECURITY: The responses you submit will be stored in a secure database that contains every response we receive (located in P2-18, Mawson Lakes Campus of University of South Australia). Your responses will not be personally identifiable in this database. The data will be summarised and published in a report. The researcher will take every care to remove responses from any identifying material as early as possible. Likewise individual responses will be kept confidential by the researcher and not be identified in the reporting of the research. Non-identifiable data will be retained for five years.

CONTACT INFORMATION: If you have any questions or concerns about this research, please feel free to contact us: Dr. Delene Weber (delene.weber@unisa.edu.au) University of South Australia (Telephone: 08-8302-5279) or Ms. Morgan Schebella (morgan.schebella@mymail.unisa.edu.au) University of South Australia (Telephone: 08-8302-3766).

SUBJECT'S RIGHTS: If you have read this form and have decided to participate in this experiment, please understand your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without penalty or consequences. Your individual privacy will be maintained in all published and written data resulting from the study. Your responses will remain confidential, unless required by law.

To participate in the study, you must meet the following conditions:

- **You are at least 18 years of age.**
- **Any questions you may have had about the study have been answered to your satisfaction.**
- **You have read the above consent form, understood it and you agree to it.**
- **You wish to participate in the above-mentioned experiment.**

If you agree to this and are willing to participate in the study, please press 'next'.

1. To the best of your knowledge, do you currently suffer from any of the following health issues?: *Heart/cardiac problems; Epilepsy*

- ○ No
- ○ Yes

2. To the best of your knowledge, do you currently suffer from any of the following health issues?: *Blood pressure issue requiring medication (e.g. hypertension)*

- ○ No
- ○ Yes

3. What gender do you identify with?

- ○ Male
- ○ Female

4. In which year were you born?

5. In general, how often do you spend leisure time in natural environments? ('Natural environments' can be any outdoor space that is not dominated by human structures, e.g.parks, reserves, beaches, conservation areas, etc.)

- ○ Never/very rarely
- ○ About once per year
- ○ Every few months
- ○ Every few weeks
- ○ About once per fortnight
- ○ About once per week
- ○ Every couple of days
- ○ Every day

6. In general, how often do you spend time in natural environments for non-leisure reasons? (e.g. when working outdoors, when walking to the bus, etc.)

- ○ Never/very rarely
- ○ About once per year
- ○ Every few months
- ○ Every few weeks
- ○ About once per fortnight
- ○ About once per week
- ○ Every couple of days
- ○ Every day

7. Briefly, how would you describe the natural environment that you visit most frequently? (i.e. what sort of setting is it, what features does it contain, etc.)

8. Is the environment you just described your ***favourite*** natural environment?

- ○ Yes
- ○ No

9. Which of the following best describes your ***favourite*** natural environment?

- ○ A beach
- ○ A sports oval or field
- ○ A community/recreation park
- ○ A conservation park or nature reserve
- ○ A linear park or trail
- ○ A botanic garden or arboretum
- ○ Other (please specify)

10. What is the highest level of formal education you have ***completed***?

- ○ Primary school
- ○ Some high school
- ○ Year 12
- ○ Bachelor degree
- ○ Masters degree or higher
- ○ Diploma or equivalent
- ○ Technical or trade qualification

11. Very briefly, how would you describe your area/s of professional expertise? (i.e. the main discipline/s of your education and/or employment: e.g. 'civil engineering' and/or 'ecology').

12. The questions in this scale ask you about your feelings and thoughts during the last month. In each case, you will be asked to indicate how often you felt or thought a certain way.

	0 Never	1 Almost never	2 Sometimes	3 Fairly often	4 Very often
In the last month, how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
In the last month, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
In the last month, how often have you felt nervous and "stressed"?	○	○	○	○	○
In the last month, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
In the last month, how often have you felt that things were going your way?	○	○	○	○	○
In the last month, how often have you found that you could not cope with all the things that you had to do?	○	○	○	○	○
In the last month, how often have you been able to control irritations in your life?	○	○	○	○	○
In the last month, how often have you felt that you were on top of things?	○	○	○	○	○
In the last month, how often have you been angered because of things that were outside of your control?	○	○	○	○	○
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

13. Have you ever worn a 'virtual reality' headset/head-mounted display?

○ Yes

○ No

14. How many times have you used a 'virtual reality' headset?

- ○ 1-2 times
- ○ 3-5 times
- ○ 5-10 times
- ○ 10-20 times
- ○ More than 20 times

15. Using the scale below, please rate the extent to which you agree with each of the following statements. Please respond as you really feel, rather than how you think "most people" feel.

	1 Disagree strongly	2 Disagree a little	3 Neither agree or disagree	4 Agree a little	5 Agree strongly
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 a part of my spirituality.	○	○	○	○	○
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.	○	○	○	○	○

16. Looking at the words and concepts listed below, please select each item that you would feel confident explaining the meaning of to another person:

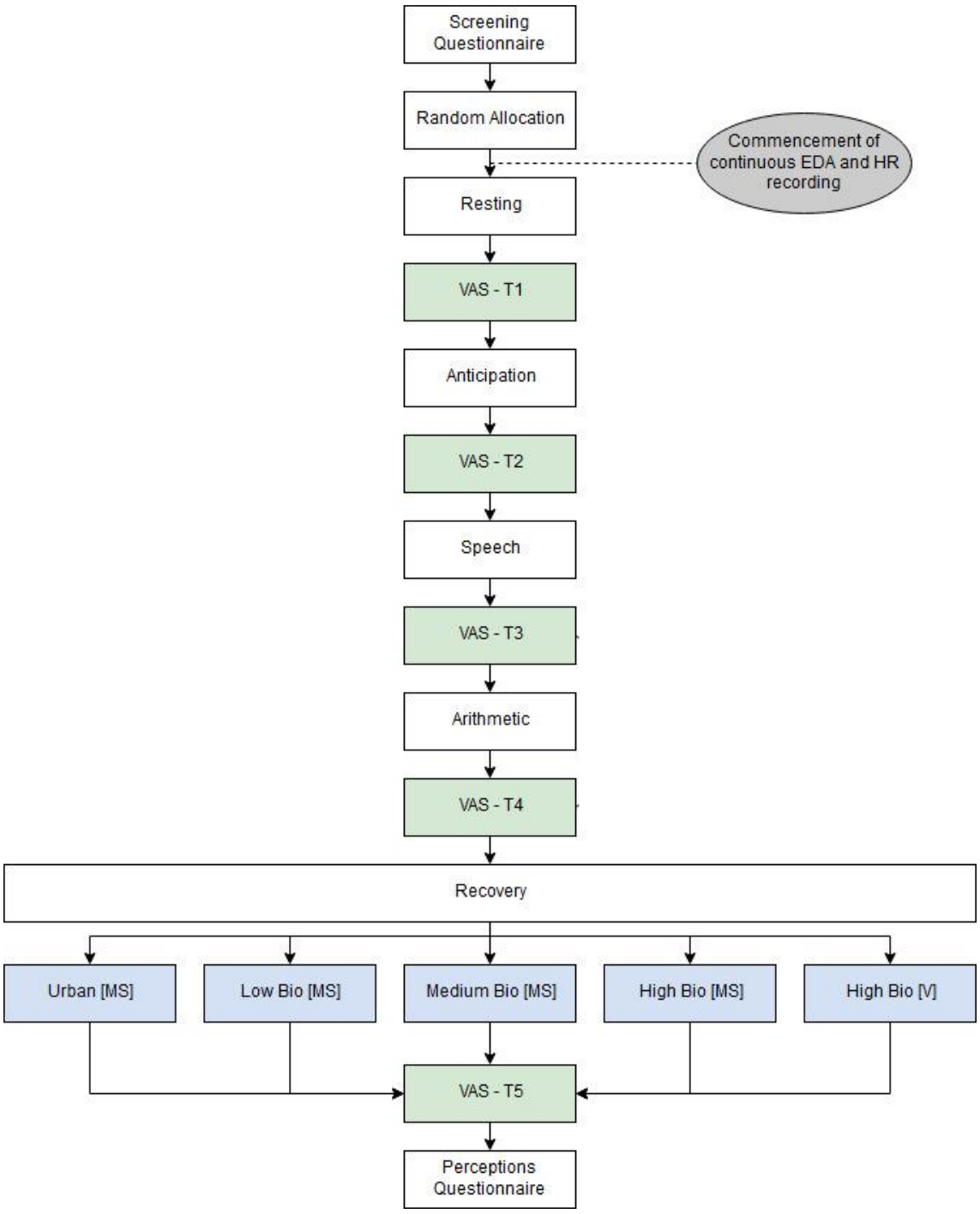
- ☐ Ecosystem
- ☐ Biodiversity
- ☐ Keystone species
- ☐ Natural capital
- ☐ Habitat fragmentation
- ☐ Endemic species
- ☐ Remnant vegetation
- ☐ Island biogeography
- ☐ Biodiversity hotspot
- ☐ Umbrella species
- ☐ Edge effect
- ☐ I would not feel confident explaining any of these concepts to another person

17. From my understanding, the direct consequences of biodiversity loss will likely include: (*please select each consequence that you believe could be **caused** by biodiversity loss*)

- ☐ Reduced food security
- ☐ Substantial ozone depletion
- ☐ Destruction of potential pharmaceuticals
- ☐ Increased spread of infectious diseases
- ☐ Rapid human population growth
- ☐ Increased frequency of natural disasters
- ☐ None of the above
- ☐ I don't know

18. Please provide a 'code name' to use during the experiment. If you think you might forget this name, please write it down and bring it with you.

Appendix J Immersive Virtual Environment experiment procedure.



Appendix K The script adhered to during the IVE experiment

Hi, welcome to the VR lab. Thank you for participating.

First, I need to confirm that you completed the pre-experiment questionnaire?

[participant should answer yes]

Great. Can I please ask you for your Code Name?

[write code name on first page of VAS – T1]

Please take a seat here while I collect some equipment.

[Participant sits. Collect wristbands and alcohol wipes from behind partition]

Now I need to clean your wrists with an alcohol wipe, and attach two wristbands, please bear with me.

[Participant sits. Attach both E4 wristbands. Warn that you need to press down firmly on their wrists]

[Connect both wristbands to phones via bluetooth]

To make sure the devices are collecting data properly, I need you to just sit here and rest for 15 minutes, so please make yourself comfortable, but try to remain fairly still. After that, I will ask you to complete a short questionnaire.

[mark event on both wristbands]

[Go behind partition. Set timer for 15 minutes]

[After 15 minutes, give participant first set of VAS and mark event]

On this piece of a paper are five scales, on which I want you to indicate how you are feeling right now. You do this by drawing a small vertical stroke on each of the five lines. I'm going to give you these same scales several times throughout the experiment.

[take back VAS once completed]

We're now going to begin the experiment, so please come and take a seat over here.

[direct participant to computer chair in main part of lab]

This part of the experiment is called the 'speech preparation segment'. You are to mentally prepare a five-minute speech about your positive and negative traits. Your speech will be recorded and reviewed by students who are taking part in a public speaking workshop this semester. You have five minutes to prepare your speech, and your time begins now.

[mark event on both wristbands]

[set timer for five minutes]

[after 5 minutes give second set of VAS]

The first activity is a speech task. You are to deliver a speech describing your positive and negative traits. We will now put the VR headset on you, and once the scene appears, you should begin your speech. Following your speech, you will be given a second task to complete.

[put VR headset and headphones on]

You should speak for the entire five-minute time period. Your time begins now.

[mark event as Matin starts video]

[set timer for five minutes]

[if participant stops talking, allow them to remain silent for 20 seconds. If they do not resume speaking, prompt the participant to continue speaking by instructing them: "**you still have time remaining**"]

[after five minute period, give third set of VAS]

[Introduce next task]

The next activity is a math task. For the next five minutes, you are asked to sequentially subtract the number 13 from 1,022. You will verbally report your answers aloud, and you will be asked to start over from 1,022 if a mistake is made. Your time begins now.

[set timer for five minutes]

[if the participant makes a mistake, prompt them with: "**that is incorrect, please start over from 1,022**"]

[after five minutes]

Please remove the headset, so that you can complete the next questionnaire.

[mark event]

[give fourth set of VAS]

This is the final part of the experiment, where you just get to relax. I'm going to put the VR headset back on you, and you can sit and rest for a few minutes in a different scene. I will return with the last few questions shortly, then you can leave.

[put headset and headphones back on]

[mark event as Matin starts nature video]

[set five minute timer]

The experiment is now over. Please complete these last few questions, and then you are free to go.

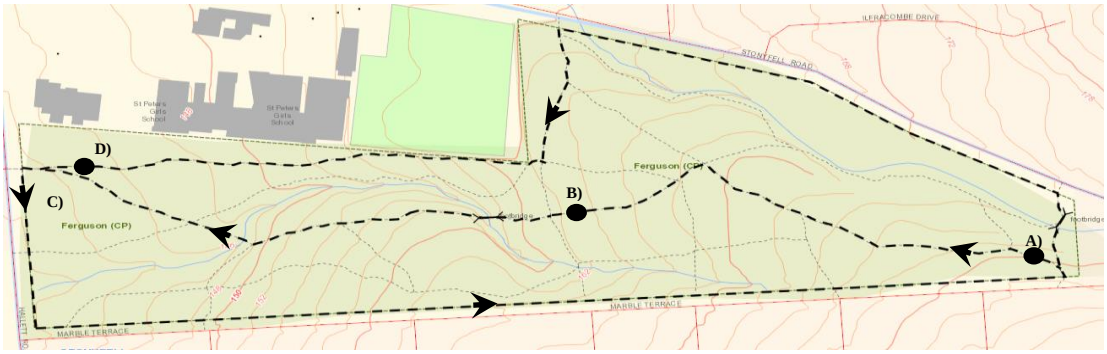
[give fourth set of VAS, bio perception questions, and immersion questionnaire]

Thank you so much for participating today. The aim of the performance tasks was to induce a stress response, but I hope it wasn't too stressful for you. None of the experiment was recorded or filmed. You can now leave. Thank you.

Appendix L The on-site assessment procedure followed during the wellbeing questionnaire study

Before assessing each site, the assessor obtained an aerial photograph of the green space from Google Earth™, to become familiar with its shape, configuration, and important landmarks. To some extent, the way in which the assessor moved throughout each park was determined by its configuration and existing walking trails, in order to prevent trampling vegetation. However, as closely as possible, the following procedure was followed:

1. Upon reaching the green space, the assessor began walking the longest linear transect through the park, towards the approximate center of the green space. Where practical this was aligned to existing trails. As they walked, they recorded the bird species they observed within or flying over the park, and marked off any relevant structural, habitat, and anthropic elements on the checklists.
2. Upon reaching the center of the green space, the assessor stopped and conducted a 10-minute period of bird observation (Point B). During this time, the assessor again recorded the bird species observed within or flying over the park. The number of individuals of each bird species was not recorded. If the bird species was not known, a description of the bird was written down to allow identification with the use of a bird identification book.
3. The assessor continued their linear transect to the opposite side of the park, then traversed the entire boundary of the green space (Point C), all the while marking off the checklists and observing the park closely in order to complete the Naturalness Index.



Example of walking route (in black) being influenced by existing trails and footpaths during on-site park assessment at Ferguson Conservation Park, Burnside Council.

Appendix M Review of literature pertaining to the psychological benefits associated with biodiversity and related attributes such as naturalness and wildness. The review focused on experiences of those attributes in specific environments, rather than aggregated attributes at neighborhood or state-level.

Study	Study Design	*n*	Country	Environment Measures	Number of Natural Sites	Assessed Perceived Biodiversity?	Wellbeing Benefits Measured	Key Findings
Fuller et al. (2007)	*Comparative* In-situ interviews with site visitors (urban green spaces)	312	United Kingdom	Species richness of birds, plants, and butterflies; number of habitat types; tree cover; park size.	15	Yes, estimation of number of plant, bird, butterfly species	Self-reported: psychological wellbeing (reflection, identity, attachment, continuity with past)	No relationship between butterfly richness and wellbeing. Other park attributes associated with some wellbeing measures: Bird richness with 'continuity with past' and 'attachment'. Plant richness with 'reflection' and 'identity'. Number of habitat types with 'reflection', 'identity', and 'continuity with past'. Park size with 'reflection', 'identity', and 'continuity with past'. Perceived plant richness increased with sampled plant richness and number of habitats, but no comparison between perceived species richness and wellbeing benefits was conducted.
Barton et al. (2009)	*Before and after* Questionnaire completed by green space users before and after visiting a National Trust site	132	United Kingdom	None, but all sites were National Trust sites and thought to be of high natural or heritage value	4	No	Self-esteem and mood	Significant improvement in self-esteem and mood after visiting sites. Conducted no comparison of benefits between sites.
Martens et al. (2011)	*Before and after* Questionnaire completed prior to and post 30-minute walk in either a wild or tended forest	100	Switzerland	'Wildness' based on expert opinion and length of time since economic use of forest (i.e. since it was last maintained)	2	No	Self-reported: wellbeing (positive affect, activation, negative affect, arousal)	Participants in the 'tended' forest exhibited a stronger increase in positive affect and a stronger decrease in negative affect than participants in the 'wild' forest. No significant differences in activation or arousal between the two sites. No differences in perceived attractiveness between the two sites.

Dallimer et al. (2012)	*Comparative* In-situ surveying of site visitors (riparian green spaces)	1108	United Kingdom	Species richness of birds, plants, and butterflies; bird density; number of habitat types; tree cover.	34	Yes, estimation of number of plant, bird, butterfly species	Self-reported: psychological wellbeing (reflection, attachment, continuity with past)	No association between perceived and actual species richness. Perceived species richness positively related to wellbeing. No association between sampled butterfly richness and wellbeing. Bird richness positively related to wellbeing. Plant richness had a negative association with wellbeing. Bird density positively associated with wellbeing, but not as strongly as perceived species richness. Tree cover associated with wellbeing.
Van den Berg et al. (2014) and associated conference paper Jorgensen et al. (2010)	*Experiment* Recovery from induced stress in different environments (videos of urban green and built sites)	102	United Kingdom	Differences in wildness and/or structural variation and/or vegetation density.	3 (and 1 built scene)	No; did assess perceived naturalness	Self-reported: mood, vitality, and restorative state	Post-recovery, there were no significant differences in mood between nature scenes, only between 'urban' and 'parkland'. .No significant differences in vitality between scenes. No significant differences in restorative state between nature scenes, only between 'urban' and 'parkland' and between 'urban' and 'wild woods'. Significant differences in perceived naturalness between scenes, with the exception of parkland and tended woodland (no difference in perceived naturalness). Significant difference in vitality between high and low perceived naturalness.
Johansson et al. (2014)	*Experiment* Appraisal of photographs of three different forest sites	35	Sweden	Differences in vegetation layers, species composition, and vegetation type.	3	Yes, Biodiversity Experience Index (BEI)	EEG; anticipated emotional response (Basic Emotional Processing questionnaire)	Biodiversity perceived accurately using the BEI. Intermediate biodiversity was the most preferred of the three forest environments. Intermediate biodiversity was appraised most positively in both EEG measurements and BEP responses.
Carrus et al. (2015)	*Comparative* In-situ surveying of site visitors (two urban and two peri-urban green spaces)	569	Italy	Ordinal biodiversity levels (low and high) based on experts ranking photographs of each site according to their biodiversity and structural complexity.	4	No	Self-reported: perceived restorativeness; and a 'wellbeing' score derived from several broad psychological and physical benefits, e.g. "feel better'	'Perceived restorativeness' and 'wellbeing' were positively associated with 'biodiversity' (high better than low) and 'location' (peri-urban better than urban). 'Wellbeing' was significantly correlated with length of visit.
Chang et al. (2016)	*Comparative* In-situ surveying of site visitors	151	Taiwan	Insect diversity, richness, evenness, and abundance	60 plots (in 3 green spaces)	No	Heart rate; electromyography (EMG); blood	Heart rate was significantly negatively correlated with insect species evenness, i.e. as evenness increased, heart rate decreased, suggesting a calming effect. Insect species

							volume pulse (BVP)	richness, abundance and diversity were not related to physiological responses.
Marselle et al. (2015)	*Before and after* Questionnaire completed prior to and post group walk in nature	127	United Kingdom	None, green spaces classified by type.	Not reported	Yes, estimation of number of plant, bird, butterfly species; also perceived naturalness	Positive and negative affect (PANAS); self-reported happiness	Post-walk negative affect significantly increased when perceived bird species increased from 0-4 to 5-14 species. Perceived naturalness and biodiversity did not correlate with post-walk emotional wellbeing but did significantly correlate with perceived restorativeness, which was in turn significantly correlated with the post-walk emotional wellbeing.
Cracknell et al. (2016)	*Comparative and Quasi-experiment* (a) Observation of aquarium visitors, (b) wellbeing responses before, during, after	(a) 112, (b) 84	United Kingdom	Number and diversity of fish and crustacean species (stocking levels: unstocked, partially stocked, and fully stocked)	1 (at three different time periods with variations in species diversity)		(a) Time spent at exhibit, (b) heart rate, blood pressure, two single-item mood scales (the Feeling Scale, the Felt Arousal Scale), five evaluative statements related to interest, enjoyment, feeling better.	(a) Visitors spent longer at the exhibit as stocking level increased. (b) All three levels of species diversity were perceived to be enjoyable and to make participants feel better. All evaluate statements were significantly more positive in the partially stocked exhibit than the unstocked exhibit, and were higher (not significantly) in the fully stocked than partially stocked exhibit. Blood pressure decreased in all exhibits, but only some significant changes. Significant decrease in heart rate in the partially and fully stocked exhibits compared with unstocked. Significant improvements in mood in partially and fully stocked exhibits, but not unstocked. Fully stocked less calming but more energizing.
Hoyle et al. (2017)	*Comparative* In-situ surveying and interviewing of site visitors	1411	United Kingdom	Typology of 9 planting types based on variations in planting structure and species character (nativeness) across three vegetation communities: herbaceous, shrub, and woodland.	31	Yes, estimation of number of plant species, native plant species, and insects	Perceived restorative effects (comfort, escape, relaxation, perception of space as unique)	Planting structure, vegetation community, and flower coverage had significant association with perceived restorativeness. Significant low-moderate correlation between perceived number of plant species and perceived restorativeness in shrub plantings. Low-moderate correlation between perceived value of planting for insects and perceived restorativeness in herbaceous plantings. No correlation between perceived biodiversity and perceived restorativeness in woodland plantings. The least natural plantings were perceived as most attractive. Landscape professionals and highly educated respondents found the plantings least restorative.

Sikorska et al. (2017)	*Comparative* Observation of green space users around lakes	NA	Poland	Aquatic, rush, and terrestrial plant species abundance; hemeroby; species diversity	28	No	Frequency of visitation and time spent in green space	No relationship between benefits and biodiversity, species abundance, or hemeroby.
Wood et al. (2018)	*Comparative* In-situ surveying of park visitors	12	United Kingdom	Habitat diversity; species richness of plants, birds, butterflies, bees	128	No	Perceived restorativeness	All parks were perceived as restorative. Ecological richness (i.e. plant, bird, bee, butterfly species richness and habitat number) explained 43% of the variance in perceived restorativeness

Appendix N

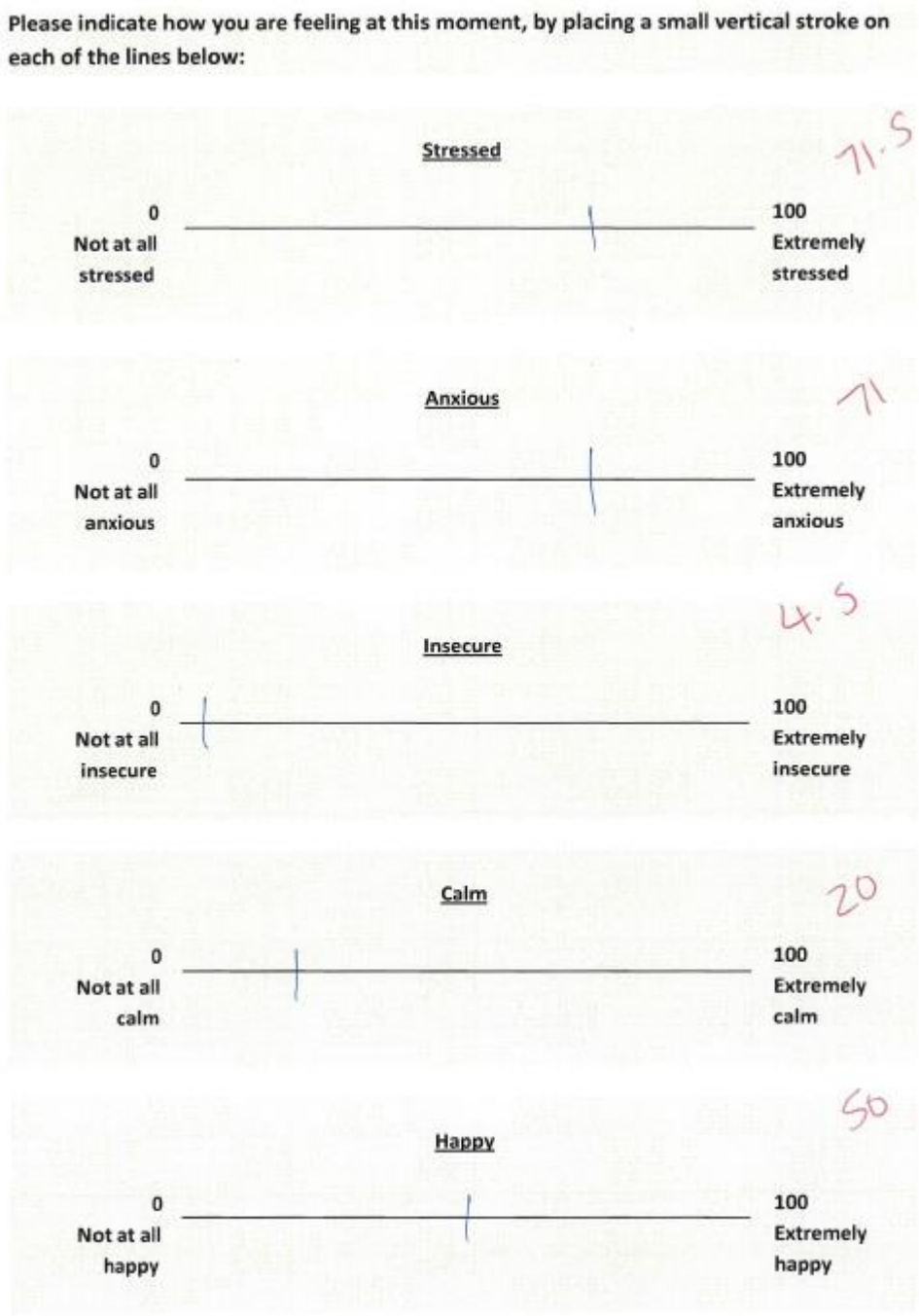
The range of values categorized as 'very low', 'low', 'moderate', and 'high' within each park attribute. Categories were formed by dividing the range of recorded values for each attribute into four equal groups, with the exception of bird species richness and habitat diversity, which could not be divided equally due to being discrete variables.

Park attribute	Level	Data range
Vegetation cover	Very low	12.2 – 27.7%
	Low	27.71 – 43.2%
	Medium	43.21 – 58.7%
	High	58.71 – 74.2%
Naturalness	Very low	35 – 49.5%
	Low	49.51 – 64%
	Medium	64.01 – 78.5%
	High	78.51 – 93%
Habitat diversity	Very low	2-3 habitats
	Low	4-5 habitats
	Medium	6-7 habitats
	High	8-10 habitats
Structural heterogeneity	Very low	7 to 11 elements
	Low	12 to 16 elements
	Medium	17 to 21 elements
	High	22 to 26 elements
Bird species richness	Very low	0-3 species
	Low	4-6 species
	Medium	7-9 species

Appendix O Mean and median wellbeing measures for each condition, over the course of the IVE experiment. Means and medians are provided, as not all responses were normally distributed at each time point. The on-site assessment procedure followed during the wellbeing questionnaire study

		T1			T2			T3			T4			T5		
Condition	**Measure**	**Mean**	**Median**	***SE***	**Mean**	**Median**	***SE***	**Mean**	**Median**	***SE***	**Mean**	**Median**	***SE***	**Mean**	**Median**	***SE***
Urban	Stress	19.70	15.25	5.37	54.95	54.75	7.15	56.20	56.25	7.02	44.40	44.00	4.87	27.26	32.25	6.30
	Anxiety	15.20	16.00	3.03	54.15	49.75	7.30	63.00	61.50	5.34	43.70	44.75	4.22	28.71	21.00	7.42
	Insecurity	16.02	5.50	7.35	44.50	40.75	8.85	54.21	57.00	9.69	39.25	37.75	6.61	18.70	16.25	4.82
	Calmness	77.05	78.25	6.13	47.61	46.25	7.63	40.15	44.25	5.00	46.75	46.25	6.46	57.30	61.75	10.09
	Happiness	67.65	64.25	5.69	44.01	47.50	6.91	34.30	36.75	5.90	51.55	49.00	7.08	59.00	62.25	7.45
	HR	70.44	71.56	3.42	73.80	74.42	2.76	83.10	84.80	3.19	78.54	77.72	3.09	71.72	72.39	2.48
Low	Stress	10.37	2.25	5.06	31.01	18.50	7.52	48.65	47.75	7.00	62.80	53.00	7.35	14.17	7.50	5.34
	Anxiety	9.96	3.00	3.75	31.70	21.50	7.75	39.45	33.50	7.28	54.25	47.50	8.86	7.35	6.75	2.13
	Insecurity	8.11	5.00	2.86	31.06	27.50	8.80	39.90	41.25	10.02	48.01	37.50	12.52	8.71	7.75	2.52
	Calmness	75.70	84.75	8.89	60.45	62.00	6.01	53.05	64.50	8.89	43.71	45.50	8.80	74.95	84.25	8.88
	Happiness	72.05	75.75	6.12	56.05	63.00	8.75	50.25	54.50	9.41	34.21	29.00	8.31	75.40	81.25	6.88
	HR	69.32	70.72	3.59	77.66	76.09	2.55	78.26	79.28	2.87	83.68	82.29	3.25	70.69	72.53	2.22
Moderate	Stress	21.55	16.50	5.49	49.20	54.50	6.34	54.55	62.50	6.82	49.20	49.00	8.46	21.51	16.75	5.32
	Anxiety	26.06	21.00	6.49	48.55	54.50	7.84	47.30	47.75	6.08	41.65	42.00	6.66	22.85	18.25	5.98
	Insecurity	6.45	6.25	1.63	24.40	16.50	7.50	36.25	38.50	7.91	26.30	21.00	6.68	15.55	7.00	5.93
	Calmness	79.50	82.50	5.14	45.30	46.75	5.09	46.70	46.75	5.91	51.45	51.75	8.11	63.45	76.00	10.68
	Happiness	71.30	69.25	5.37	55.55	54.00	6.96	55.20	57.00	8.51	52.10	56.25	8.40	77.95	78.75	3.96
	HR	71.55	72.28	3.58	71.20	71.52	3.28	76.43	79.83	4.38	73.73	73.71	3.17	71.76	69.62	3.11
High-M	Stress	9.60	8.50	2.51	33.64	27.00	7.53	52.73	50.00	9.08	53.23	46.50	9.59	13.28	7.50	4.98
	Anxiety	16.19	8.50	5.21	45.27	34.50	9.12	58.09	61.00	9.54	53.23	46.00	9.82	12.16	5.50	5.30
	Insecurity	15.25	2.50	6.87	43.05	31.50	10.16	54.10	69.00	11.93	44.15	32.50	10.70	13.01	5.00	5.68
	Calmness	63.18	65.00	10.63	41.19	49.00	9.28	38.37	49.00	10.71	41.56	48.00	10.33	74.18	80.00	9.20
	Happiness	70.45	71.00	4.47	48.64	50.50	7.72	41.05	45.00	8.97	39.10	36.50	9.40	72.55	80.00	7.43
	HR	75.60	78.37	3.92	80.39	80.52	2.58	83.77	85.89	2.29	84.41	86.00	1.71	77.16	78.20	1.72
High-V	Stress	11.45	4.50	4.22	27.91	24.00	5.08	32.00	29.00	6.54	38.64	39.50	7.40	12.18	10.00	3.11
	Anxiety	12.68	6.00	5.46	29.09	20.00	6.46	30.09	26.00	6.39	32.82	22.50	7.39	13.36	9.00	3.73
	Insecurity	3.60	1.50	1.35	14.91	5.00	6.09	22.18	16.00	7.00	29.50	23.00	8.67	10.87	8.00	2.81
	Calmness	74.14	86.00	9.38	62.95	68.00	6.70	50.91	50.50	6.98	48.55	52.50	8.52	73.86	85.50	7.68
	Happiness	69.64	68.50	4.74	67.32	69.00	5.23	65.68	75.00	7.11	58.27	64.50	7.44	76.05	79.00	5.08
	HR	70.79	72.74	2.75	74.13	73.82	1.93	79.03	79.08	3.07	81.32	83.61	1.89	76.82	73.38	2.97

Appendix P Sample Visual Analog Scales from the IVE biodiversity experiment



Appendix Q Perception questionnaires used in the IVE biodiversity experiment

Perception of environmental attributes

How would you rate the scenic beauty of the environment you just experienced?

1	2	3	4	5
Very unattractive				Very attractive

How would you rate the diversity of species in the environment you just experienced?

1	2	3	4	5
Very low diversity				Very high diversity

How would you rate the 'nativeness' of the species in the environment you just experienced?

1	2	3	4	5
Entirely exotic or introduced				Entirely native

How aware were you of 'weeds' in the environment you just experienced?

1	2	3	4	5
I didn't notice weeds				I noticed a lot of weeds

Biodiversity Experience Index (BEI)

Please rate the extent to which you think each of the following phrases describes the virtual environment you just experienced:

'Wild'

1	2	3	4	5
A little				Very much

'Rich in plant species'

1	2	3	4	5
A little				Very much

'Varied'

1	2	3	4	5
A little				Very much

'Rich in animal species'

1	2	3	4	5
A little				Very much

Telepresence questionnaire

Please indicate the extent to which you agree with each of the following statements by circling a number on the scale below:

1. **When the virtual environment ended, I felt like I came back to the "real world" after a journey.**

1	2	3	4	5
Strongly disagree				Strongly agree

2. **The headset created a new world for me, and that world suddenly disappeared when the virtual environment ended.**

1	2	3	4	5
Strongly disagree				Strongly agree

3. **During the experiment, I felt I was in the world the headset created.**

1	2	3	4	5
Never				Always

4. **Whilst in the virtual environment, I NEVER forgot that I was in the middle of an experiment.**

1	2	3	4	5
Never				Always

5. **I felt like my body was in the room, but my mind was inside the world created by the virtual environment.**

1	2	3	4	5
Never				Always

6. **During the experiment, the virtual environment was more real or present for me than the "real world."**

1	2	3	4	5
Never				Always

7. **The virtual environment seemed to me only "something I saw" rather than "somewhere I visited."**

1	2	3	4	5
Strongly disagree				Strongly agree

8. **During the experiment, my mind was in the room, not in the world created by the virtual environment.**

1	2	3	4	5
Never				Always

9. **I was completely captivated by the virtual world.**

1	2	3	4	5
Strongly disagree				Strongly agree

10. **How 'real' did the virtual world seem to you?**

1	2	3	4	5
Not real at all				Very real