

Wellbeing and urban living: nurtured by nature

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Abstract

In recent decades, empirical evidence has demonstrated that nature can enable urban environments to support human wellbeing. Research into links between nature and human wellbeing is often carried out with one wellbeing index or in single locations, which can limit our understanding of findings. To further this work, we deployed an online survey to residents of the two most-populous cities in both Australia and New Zealand. The survey measured self-reported wellbeing via three indices used widely in the literature: general wellbeing (WHO-5), personal wellbeing, and psychological wellbeing. We compared results with two biodiversity indicators: bird species richness and the Normalised Difference Vegetation Index (NDVI) of respondents' postcodes. We also asked respondents to rate the amount of nature they view from their immediate environment: both at home and at work or other frequent location. Our results support a link between local nature and human wellbeing across all four cities, significantly in the two Australian cities. Qualitative data reveals that urban life can challenge human wellbeing by creating a unique suite of stresses that residents strive to balance. There is the potential for nature to support human wellbeing in typically degraded urban environments. While this work corroborates existing literature demonstrating links between human wellbeing and nature, our qualitative research extends our understanding of these links by providing more detailed and nuanced information.

Keywords: Wellbeing, NDVI, biodiversity, urban, WHO-5

Introduction

With most of the world's population living in urban areas (WHO 2010), it is critical that urban environments are planned and maintained to promote the wellbeing of residents. There

are obvious benefits to living in cities, including greater access to health and social services, and opportunities for education (WHO 2010). However urbanisation is also associated with environmental degradation and pollution, over-crowding, increased incidences of both communicative and chronic disease, increased mental and emotional disorders, higher rates of violence, crime and suicide, and there are greater social and financial inequalities among urban populations (WHO 2010). Whether the benefits associated with living in cities outweigh the hazards is yet to be demonstrated (Dye 2008). The proportion of people living in urban areas is projected to increase over time, such that 67% of the total human population will be living in urban areas by 2050 (United Nations 2012). Opportunities to protect and bolster the wellbeing of urban residents should be pursued.

Links between human wellbeing and nature are well established (for example, Sandifer et al. 2015). To be clear about what we mean by ‘nature’ and ‘wellbeing’, which are terms used in multiple contexts across multiple disciplines, definitions of key terms used in this paper are presented in Table 1. Humans exposed to different amounts of nature have demonstrated responses in a number of ways, including physiological (van Den Berg and Custers 2011), emotional (Hartig et al. 2003), and psychological (Dallimer et al. 2012). One of the most common measures of how people experience life in proximity to nature has been through self-reported responses acquired via questionnaire (de Vries et al. 2013). Single case studies that have found links between human wellbeing and nature have focused on discrete locations, single cities (such as Sheffield, UK, in Dallimer et al. 2012), or multiple locations within one country (such as in four Dutch cities in de Vries et al. 2013). However old European cities, for example, are likely to differ ecologically from newer cities in, for instance, New Zealand in terms of the proportion and quality of native habitat and the remaining wildlife. Making international comparisons between cities enables researchers to

assess how modification of the natural habitat differs in each city and whether that changes how urban residents interact with their environment (Niemelä et al. 2009). There are also advantages to increasing the scale of such research to consider multiple cities, even multiple countries, in order to uncover any patterns that might be culturally specific (Kabisch et al. 2015). How residents interact with nature in cities is affected by social and cultural aspects of societies and this has implications for how their wellbeing is affected (Hartig et al. 2011). Multi-city studies have the potential to inform syntheses that make recommendations that are relevant to multiple populations and to improve understanding about underrepresented areas (Kabisch et al. 2015). Undertaking investigations into the relationships between nature and wellbeing in Oceania is also relevant given that a majority of the literature is situated in the northern hemisphere (Kabisch et al. 2015) and other parts of the world are under-investigated.

The World Health Organisation definition of health (Table 1) recognises that health is complex; it is more than a physical state, and our physical health interacts with internal (emotional, mental) and external (social) aspects as well. For instance, emotional wellness can also promote resilience against stressors that threaten our mental and physical health (Matheson et al. 2006; Yancura and Aldwin 2008). The WHO definition also recognises that health is more than a lack of illness: it is an active state of wellness. ‘Wellbeing’ arguably takes this definition further. Wellbeing has emerged as a means to evaluate populations without the problems associated with using the gross domestic product (GDP) to measure nations’ living standards (Bates 2009; Krueger and Stone 2014). Wellbeing is often considered synonymous with happiness because it represents an overall satisfaction with one’s life (Diener et al. 2003). Supporting the WHO’s complex notion of health, subjective assessments of wellbeing have been associated with physical states, such as hormonal or

immunological responses (Cohen and Hamrick 2003; Smyth et al. 1998), and even mortality (Steptoe et al. 2013). There are numerous self-reported wellbeing indices, each measuring different things depending on the focus of the authors or reporting body, such as, the Organization for Economic Cooperation and Development’s (OECD) Better Life Index (OECD 2014). Such indices contribute to understanding about the wellbeing of populations, but it is important to align any research question with the elements that make up the index. That is, the instrument should either be appropriate to the research question, to the populations, or to a combination of both elements.

Our study explored links between nature and human wellbeing across four cities in Australia and New Zealand. The aim was to test whether exposure to nature benefits urban residents’ wellbeing in major cities of Oceania. We used three indicators of nature: vegetation, bird species richness, and nature visible from home or work. We measured wellbeing by using three distinct indices to test for differences across cities.

Table 1. Definitions of key terms used in this study

Term	Definition
Health	An overall state of health, including social, mental and physical factors; more than a lack of disease (WHO 1947)
Nature	Nonhuman features and processes including all vegetation and animals, water, air, geological processes and landscapes (Hartig et al. 2014)
Urban	Areas of dense human populations where economic outputs are focussed on industry, service and technology (instead than farming) (WHO 2010)
Wellbeing	How humans evaluate and experience their lives overall (Stone et al. 2014)

Method

We conducted this research in four cities: Auckland and Wellington in New Zealand, and Melbourne and Sydney in Australia. (ABS 2013; Statistics New Zealand 2006). These cities were selected as they are the two most-populous cities of Australia and New Zealand, and they all share a similar climate based on average annual temperatures (minimum and maximum) and precipitation (Peel et al. 2007) (Online Resource 1). Variables used are listed in Table 2. Urban areas were defined by the postcodes included in the geographic information system (GIS) boundaries supplied by the appropriate governmental bodies for the greater urban areas (New Zealand Post and the Australian Bureau of Statistics). These boundaries included greater city areas, including outer suburbs. Respondents were asked to provide their postcode in order to locate them within each city in a non-intrusive manner.

In 2013, the online survey was made available to the public via a website (www.whoneedsnature.com). Responses took between 10-15 minutes each. The survey was available for six months (November 2013-April 2014), including months from the southern hemisphere's Spring, Summer, and Autumn, to reduce the impact of disorders associated with specific seasons, such as seasonal affective disorder. The website was shared via media releases to Australian and New Zealand organisations, and with local councils in each of the four study cities. Targeted advertising to residents of the four study cities was undertaken via Facebook, and a social media presence was maintained with posts pertaining to urban nature (not the survey *per se*) for the duration of the survey (i.e., Twitter, Instagram, Facebook). After four months, postcards advertising the study were distributed in public places in each of the study cities (Online Resource 2).

The 1903 responses were cleaned, with entries from postcodes external to the study cities, dummy postcodes, and test entries removed. The remaining 1819 valid quantitative responses were analysed using a combination of Microsoft Excel and JMP Pro 9.0.0. We used principle components analyses to create wellbeing indices that integrated the questions of three wellbeing instruments, described below, and ran linear regressions with measures of nature. This approach enabled us to treat the wellbeing measures independently and make comparisons between study cities. In all four cities, between 0.011-0.020% residents of each city responded to the survey (Auckland: 159; Wellington: 85; Melbourne: 700; Sydney: 875).

Ethics approval for the web survey was provided by the University of Sydney Human Research Ethics Committee. Participation was voluntary and responses anonymous. There were two versions of the web survey – one for each country (Australia and New Zealand). The difference between the two surveys reflected different examples of native species where example species were included. In every other respect the two surveys were identical.

Table 2. Variables measured in this study. Biodiversity indicators (avian species richness, NDVI, nature viewed from home and work), three wellbeing indices, and demographics. An open-ended comment was also invited.

Variable	Scale	Description	Data source
Avian species richness	Postcode and Urban area	The number of bird species recorded	http://biodiversitymapping.org – GIS
Vegetation	Postcode and Urban area	The normalised difference vegetation index (NDVI)	NDVI – GIS (Landsat scenes downloaded from http://earthexplorer.usgs.gov)

General wellbeing (WHO-5)	Postcode	5-item World Health Organization self-reported wellbeing index (Psychiatric Research Unit 1998)	Survey
Personal wellbeing	Postcode	10-item personal wellbeing based on the Personal Wellbeing Index developed by Cummins et. al (2003)	Survey
Psychological wellbeing	Postcode	7-item psychological wellbeing based on the reflection axis used in Dallimer et. al (2012)	Survey
How much nature do you see from your window at home, and at the place other than your home where you spend most of your time (e.g., work)	Postcode	2 items asking respondents to rank how much nature they can see with five options (almost all man-made; mostly man-made; half man-made-half nature; mostly nature; almost all nature) based on a study of inner-city children (Faber Taylor et al. 2002)	Survey
Demographics	Postcode and		Survey
- Age	Urban area	- Categorical 10-year groups (18-	
- Gender		76+)	
- Marital status		- Categorical (female; male)	
- Household composition (adults, children, pets)		- Categorical (single; married/de facto)	
- Duration of residence		- Number of resident types	
- N. Bedrooms of residence			
- Highest level of education		- Number of years	
- First language		- Number of bedrooms	
		- Categorical (qualification type)	
		- English or open answer	
General comment (free text field)	Individual responses	“If you have any comments you would like to make about any aspect of the	Survey

survey, please note them here. This

question is optional.”

Wellbeing

Three common wellbeing indices were used. The WHO-5 (Psychiatric Research Unit 1998) is a five-item, generic questionnaire that can measure the self-reported wellbeing of populations around the world (Topp et al. 2015). It is a useful index given its global usage, clinimetric validity (Topp et al. 2015) and application regardless of disease. While typically used to refer to the previous two weeks, due to the duration of the survey (four months), respondents were asked to consider the previous four weeks when answering. The second index was designed as a national indicator of self-reported personal wellbeing for Australia (Cummins et al. 2003). Personal wellbeing is a measure of life satisfaction comprising seven domains that are averaged together (Cummins et al. 2003). We deemed this index useful because of its local focus and broad use in one of the study countries, Australia. Two questions were omitted from the personal wellbeing index as they were not considered critical to the research question, the optional ‘religion/spirituality’ and ‘personal relationships’ questions, but the optional ‘general life satisfaction’ question was included. The third index we selected is a psychological wellbeing index. It was relevant to include a specific psychological measure in this survey, particularly one that has been used in conjunction with biodiversity in the past (i.e., in Dallimer et al. 2012). Questions were reworded to refer to ‘local nature’ instead of ‘this park’, as our survey refers to a respondent’s local nature rather than a specific location. We used principal components analysis for each wellbeing item to create indices for general wellbeing (WHO-5), personal wellbeing, and psychological wellbeing (Online Resource 3). We ran linear regressions for each city between wellbeing indices and nature, as measured by NDVI and bird species richness.

Nature

We used a combination of human survey and GIS data analysis to measure aspects of nature (Table 2). Two indicators of nature were used: the amount and vigour of vegetation, and bird species richness. The NDVI and bird richness was calculated for each survey respondent's postcode.

The normalised difference vegetation index (NDVI) measures the presence of vegetation and its photosynthetic vigour (Pereira et al. 2012) and was calculated from Landsat 8 satellite imagery. NDVI has been shown to have a positive relationship with species richness in urban areas, for example, with birds (Bino et al. 2008). The Landsat 8 scenes were taken between June and November 2013 when the survey was commencing, and when scenes could be seen without cloud and during daylight hours. The conversion of digital numbers to top of atmosphere reflectance (USGS 2015) was completed using Exelis VIS ENVI 5.2. We performed the analysis in ArcMap 10.2 to produce the mean and standard deviation NDVI per postcode for all four cities.

We used avian species richness data from biodiversitymapping.org (accessed 10 August 2015), where the authors of previous works (Jenkins et al. 2013; Pimm et al. 2014) make the data publicly available for research. Avian species richness data was obtained from BirdLife International (BirdLife International and NatureServe 2014). Mean species richness and standard deviation were calculated using ArcMap 10.2.

In the online survey, two questions asked respondents how much nature they see from windows in their home, and at the location other than home where they spend the most amount of their time (such as work or university) based on a questionnaire used for inner-city children (Faber Taylor et al. 2002). This subjective measure of nature near home and the second-most regular location of participants was relevant because it reflects participants'

immediate experience of nature on a daily basis. Furthermore, how people perceive ‘naturalness’ (van den Berg et al. 2014), biodiversity (Dallimer et al. 2012), and environmental ‘quality’ (Swanson et al. 2015) could have a stronger effect on their wellbeing than ecological descriptors of an environment.

Qualitative responses

The final survey question (Table 2) was an open question intended to allow respondents to raise any issues or responses that were not explicit throughout the survey.

A total of 386 respondents chose to add a comment at the end of the questionnaire (Auckland: 29; Melbourne: 149; Sydney: 197; Wellington: 11). Qualitative responses to the final question were analysed using QSR NVivo (QSR 2012). Initial coding was performed by one researcher, taking a grounded theory approach to allow unprompted ideas to emerge (Glaser and Strauss 1967). Grounded theory was considered the appropriate methodology given that the question was intentionally general and there were no expectations of the responses. The first researcher identified as many topics that could be identified. A second, more focused coding was performed to confirm which topics overlapped with or were related to other topics. Sets or dimensions of responses were created to reflect the main topics covered by the general comments and were discussed with the second researcher to ensure agreement (as per meetings to discuss emerging interpretations used in Sbaraini et al. 2011).

Survey demographics

We included the following demographic questions in the survey: age group (18-25, 26-35, 36-45, 46-55, 56-65, 66-75, 76+), gender, marital status, highest qualification, the composition of households (including adults, children, pets), the number of bedrooms in the

home, the duration of living in the current home, and respondents' first language. We used a general linear model to look at how different demographic variables influenced general wellbeing (WHO-5), personal wellbeing, and psychological wellbeing indices.

Results

Wellbeing

The first principal component for each wellbeing index loaded positively with all questions; the second principal components all explained less than 1 standardized unit of variance (Online Resource 3). General wellbeing (WHO-5) was positively associated with NDVI in Melbourne, Sydney and Wellington, significantly in the Australian cities (Table 3). Personal wellbeing was positively associated with NDVI in all cities, significantly in Melbourne and Sydney. Psychological wellbeing was positively related to NDVI in the Australian cities, particularly in Sydney. Neither general wellbeing nor personal wellbeing were correlated with bird species richness. How much nature respondents said they saw from home or work was positively correlated with all wellbeing indices (Table 3). The most significant results were reported in Auckland, Melbourne and Sydney.

Across all four cities, responses to the general wellbeing (WHO-5) and personal wellbeing indices were similar, but the levels of NDVI and bird species richness were significantly different ($P < 0.0001$; Table 4). Psychological wellbeing also differed significantly among cities ($P = 0.040$; Table 4).

Table 3. Linear regressions of mean NDVI, bird species richness, and how much nature respondents said they viewed from home or work compared with wellbeing indices. Significant results are bolded.

	Auckland					Melbourne					Sydney					Wellington				
	β	F	DF	P	R ²	β	F	DF	P	R ²	β	F	DF	P	R ²	β	F	DF	P	R ²
NDVI Mean																				
General wellbeing	-1.25	1.33	1,121	0.251	0.01	1.41	6.10	1,571	0.014	0.01	2.47	14.34	1,765	<0.001	0.02	0.61	0.26	1,63	0.611	0.00
Personal wellbeing	0.47	0.21	1,120	0.649	0.00	1.43	5.30	1,568	0.022	0.01	2.62	13.36	1,757	<0.001	0.02	0.68	0.27	1,63	0.603	0.00
Psychological wellbeing	-0.13	0.01	1,130	0.914	0.00	0.90	1.96	1,597	0.162	0.00	2.29	11.42	1,796	0.001	0.01	-2.68	3.87	1,67	0.053	0.05
Bird species richness																				
General wellbeing	0.00	0.18	1,121	0.671	0.00	-0.00	0.02	1,563	0.886	0.00	-0.00	0.47	1,751	0.494	0.00	-0.01	0.85	1,63	0.359	0.01
Personal wellbeing	0.00	0.56	1,120	0.457	0.00	-0.01	1.37	1,560	0.242	0.00	-0.00	0.08	1,746	0.780	0.00	0.01	0.13	1,63	0.723	0.00
Psychological wellbeing	0.00	0.93	1,130	0.337	0.01	0.01	4.70	1,587	0.031	0.01	0.00	0.00	1,782	0.961	0.00	0.03	2.47	1,67	0.121	0.04
How much nature at home																				
General wellbeing	-0.02	0.61	4,112	0.655	0.02	0.25	3.14	4,548	0.014	0.02	0.34	6.45	4,727	<0.001	0.03	0.02	0.49	4,56	0.744	0.03
Personal wellbeing	0.46	2.20	4,111	0.074	0.07	0.24	2.97	4,544	0.977	0.00	0.46	10.29	4,720	<0.001	0.05	0.49	1.58	4,56	0.193	0.10
Psychological wellbeing	0.69	3.18	4,121	0.016	0.10	0.03	0.12	4,573	0.019	0.02	0.15	2.05	4,753	0.085	0.01	0.02	1.34	4,60	0.264	0.08
How much nature at work																				
General wellbeing	0.65	3.26	4,100	0.015	0.12	0.24	2.81	4,515	0.025	0.02	0.18	2.73	4,674	0.028	0.02	0.05	1.55	4,53	0.202	0.10
Personal wellbeing	0.62	3.89	4,99	0.006	0.14	0.04	0.46	4,512	0.765	0.00	0.22	3.03	4,666	0.017	0.02	0.09	0.61	4,53	0.659	0.04
Psychological wellbeing	-0.01	0.63	4,108	0.643	0.02	0.08	0.54	4,540	0.704	0.00	0.14	1.32	4,703	0.260	0.01	0.22	0.51	4,56	0.728	0.04

Table 4. Responses to the general wellbeing (WHO-5) and personal wellbeing indices were similar across all four study cities. There were differences in how Psychological wellbeing, NDVI and Bird species richness were reported. Bolded figures are significant.

Variable	ChiSquare	DF	P
WHO-5	3.63	3	0.304
Personal wellbeing	7.19	3	0.066
Psychological wellbeing	8.31	3	0.040
NDVI (postcode)	50.08	3	<0.001
Bird species richness (postcode)	1357.55	3	<0.001

Nature

The interquartile variation across cities demonstrates a range of vegetation and bird species present (Figure 1). There were more bird species in Australian cities than in the New Zealand cities.

Respondents who reported having greater nature at home were significantly more likely to live in a postcode with higher NDVI (Table 5). Respondents with at least some nature at home were situated in postcodes with higher bird species diversity (Table 5). There was a significant relationship between NDVI and bird species richness.

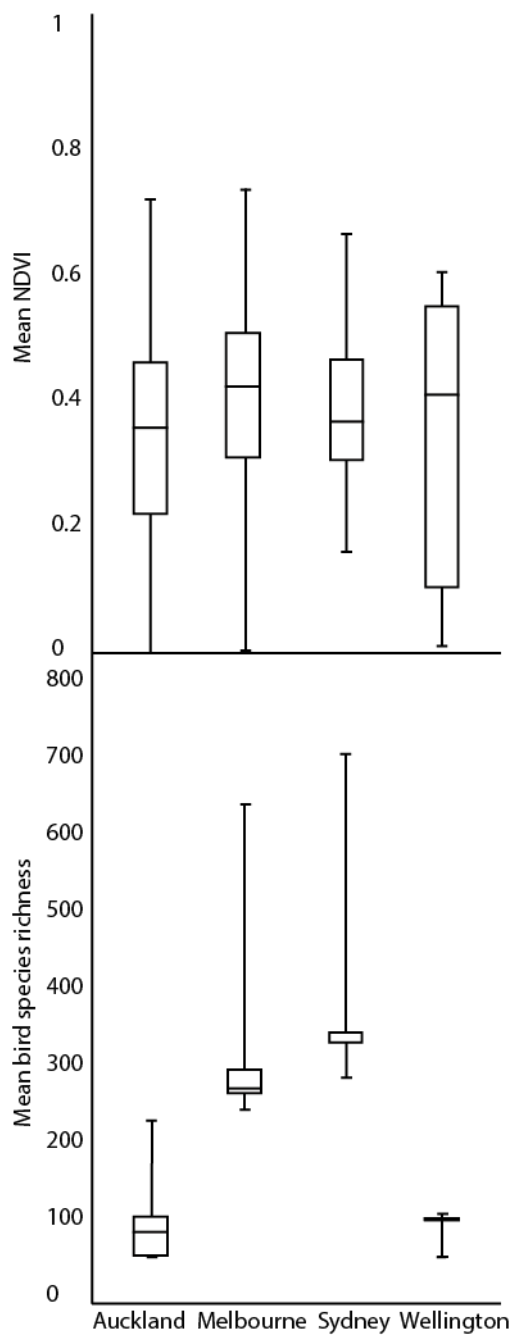


Figure 1. The NDVI and bird species richness varied across the four study cities. Whiskers show the minimum and maximum ranges, and boxes show the interquartile ranges within respondents' postcodes, either side of the median.

Table 5. Linear regressions of the NDVI and bird species richness per postcode compared with other variables. Significant relationships are bolded.

	Auckland		Melbourne		Sydney		Wellington	
	P	R ²	P	R ²	P	R ²	P	R ²
NDVI Mean								
How much nature at home?	0.141	0.05	<0.001	0.26	<0.001	0.24	0.083	0.11
How much nature at work (or similar)?	0.566	0.02	0.015	0.02	0.014	0.02	0.142	0.10
General wellbeing	0.251	0.01	0.014	0.01	0.000	0.02	0.611	0.00
Personal wellbeing	0.460	0.00	0.028	0.01	0.001	0.02	0.588	0.00
Psychological wellbeing	0.913	9.07	0.179	0.00	<0.001	0.01	0.053	0.05
Bird richness of postcodes (mean)	0.074	0.02	<0.001	0.19	<0.001	0.13	<0.001	0.14
Bird richness								
How much nature at home?	0.363	0.03	<0.001	0.06	<0.001	0.07	0.930	0.01
How much nature at work (or similar)?	0.557	0.02	0.787	0.00	0.677	0.03	0.044	0.14

Qualitative responses

Although comments were coded separately for each city, themes were coherent across all locations. Focussed coding revealed four sets or dimensions of comments: those concerning the survey itself, nature, wellbeing, and urban life. For instance, the following comment, also discussed above, is included in all three dimensions (nature, wellbeing and urban life): “There is a park near where I live. It is great to have but it is right on the train line... I do not always feel rested and calm. When I go to nature without hearing trains I feel calm and peaceful.” This is because the comment initially fits into the nature dimension: parks and nature are mentioned; the sense of feeling calm, peaceful and rested (or not) fits with the wellbeing dimension; and the juxtaposition of these themes with themes about transport and noise also fit into the urban life dimension. Themes can be relevant to more than one dimension, for example, the vegetation theme might be relevant to both the nature and the wellbeing; for example, “I think the quantity of nature and trees has a direct effect on happiness” applies to both nature and wellbeing dimensions.

More than half of those who commented (n = 200) made at least part of their comment about the survey itself. This included positive responses to the survey, suggestions, or complaints. Seven respondents' comments indicate that their awareness of local nature would be heightened after completing the survey; "I live in a unit but enjoy the nature around my area. This survey has made me think more about appreciating it even more." Some respondents (n = 10) noted that they were new to the area in which they live, such as, "Not Australian, from the UK, so don't have much knowledge in native animals and birds."

Wellbeing dimension

The wellbeing dimension includes comments concerning themes listed in Table 6. Some respondents made it clear that nature did not cause their unhappiness or negative state, such as "sometimes I think the reason I don't feel calm or am able to ponder life in a park is because I need to watch my 2 year old". Some respondents felt nature supported their wellbeing or recovery from a difficult time, for example, "I have long-term depression which I am being treated for. Going to the local bush and pulling up weeds one morning per week is a great help to me". In general, wellbeing is complex and multiple factors are involved. Nevertheless, nature provides some support to most respondents who left comments relating to wellbeing.

Table 6. Example comments demonstrate the range of themes that formed a dimension about wellbeing.

Theme	Example comment
Children/family	"I have a very young baby & a toddler so I think my health/emotional state is more linked to that than nature in [the] area!" – Melbourne respondent
Exercise	"Being able to walk my dog down at the beach, or go up in to the hills is a great stress relief and keeps me fit and healthy and best of all it's free." – Wellington respondent
Pets	"I hope this raises awareness of the value of green space to personal wellbeing. I love my garden and the birds and insects it gives shelter to, and I need public parks in which to

	exercise my two dogs.” – Melbourne respondent
Vegetation	“Having a small vegetable garden and flowers in pots makes me feel happy and content.... It is wonderful to see things grow in the city.” – Sydney respondent
Wildlife	“I couldn't bear to live without green spaces. Living where I do I am incredibly lucky to have access to wetlands, rivers and woodland with a huge diversity of plants and animals. I can live without highways but I can't live without nature.” – Sydney respondent
Rejuvenation	“I need to be around natural light, fresh air, flora & fauna as it impacts how I think, feel & act. I feel more free & restored around nature.” Sydney respondent
Safety	“[I] love native secluded bush walks in city but concern over safety, when alone, trumps this.” – Auckland respondent
More detail about life situation	“I have had a broken leg the past month - so this may affect results focusing on health and wellbeing.” – Melbourne respondent
Happiness and wellbeing	“I suffer from anxiety and depression. I keep a garden on my balcony which I find helps my mental and physical health.” – Sydney respondent

Nature dimension

Themes in the nature dimension are demonstrated in Table 7. The nature dimension described respondents’ reactions to non-human animals and plants, including topics of concern (such as degradation of wilderness areas), experiences of nature, and thoughts or recommendations about how people should preserve or interact with nature. No single natural profile was preferred, but comments suggested that a variety of nature is valued by respondents: “I felt a bit manipulated when I had to choose between fountains and natural water systems - both are good!” There was a perceptible thread of comments that reflected an awareness of colonialism and differences in culture (n.11) where respondents analysed their preferences of nature, such as, “My preference is for introduced plants and trees as I have European roots.”

Table 7. Example comments demonstrate the range of themes that formed a dimension about nature.

Theme	Example comment
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Conservation	“I strongly believe that we need to put in more effort to educate the public on the importance of their actions towards nature. ...I hope that we can preserve nature as it is and not degrade it further.” – Melbourne respondent
Custodianship	“Glad to do what I can to help nature, after all God placed us here and positioned us as custodians of the planet.” – Sydney respondent
Culture	“We don't actually feed birds - we provide water. The vegetation question is a tricky one: I love natural bush, but enjoy exotic gardens and parks aesthetically. The colonial's dilemma.” – Sydney respondent
National parks	“I feel more rejuvenated by visiting a national park with incredible vistas and natural landscapes.” – Sydney respondent
Urban parks	“There are not many inner city places where you can feel a sense of nature untamed. Most parks are manicured and resemble little of the Australian bush.” – Melbourne respondent
Native animals and plants	“I love native plants and animals and believe they are important for a city for OUR sake, but I do feel that a city is an unsafe environment for most native animals.” – Sydney respondent
Weeds or pest animals and plants	“We have feral cats breeding... I don't feel at ease or relaxed in the parks nearby due to the lack of foresight and planning and the amount of trash and weeds everywhere” – Sydney respondent
Pets	“There should be more open spaces around where I live and more off the leash parks so we can take our dogs and to allow them to run around.” – Sydney respondent
Wildlife	“We usually see lots of spiders and lizards/ cicadas in our yard/house but have not noticed any lately. Lorikeet flock has diminished.” – Sydney respondent
Vegetation	“I do think growing population means sacrificing nature for our needs, but I hope we bring plants, herbs and our kind of vegetation closer to home - even rooftops could provide new types of garden.” – Auckland respondent

Urban life

The urban life dimension was not anticipated as it was not part of the survey questionnaire. However, respondents were asked to complete the survey if they lived in an urban area and any postcodes that fell outside the urban boundaries were excluded. Example comments from themes that feature in the urban life dimension are included in Table 8. The management and governance of urban spaces was

relevant, but respondents also recognised that their personal situations affected their interaction with nature. For example, the following comment reflected economic struggle, initiatives such as growing food at home, being responsible for pets and managing stress: “Any dissatisfaction is due to current financial climate and the struggle to pay bills, buy food etc. I’m growing as much as I can and swapping home grown food with friends where I can. Being able to walk my dog down at the beach, or go up in to the hills is a great stress relief and keeps me fit and healthy and best of all it’s free” (Wellington participant). Variants of this kind of comment revealed that urban life is stressful, can involve trade-offs in values, and can require a balancing act to maintain.

Table 8. Example comments demonstrate the range of themes that formed a dimension about urban life.

Theme	Example comment
Urban life as a balancing act	“I am not completely satisfied in terms of where I live, since if I had the choice, I would choose to live outside of the city in a more rural location surrounded by nature, but I can’t move because of the kind of work I do. But, overall I feel lucky to live near the beach (nature) and so I am content. We pay more than we can afford to live as close to nature as possible in the city.” – Sydney respondent
Culture	“If activities can be integrated with natural elements, it’s even better... The mix of natural and cultural landscapes is exactly what makes my area so nice to live in.” – Sydney respondent
Development	“East/West link is having a MAJOR downer on my emotional state. Royal Park being destroyed is the WORST thing in my world at the moment.” – Melbourne respondent
Dissatisfaction	“I have 2 young kids under 6 yrs and my husband is working really hard in achieving our financial goals. I feel that other than being a full-time mum and house wife, I am not fulfilling my potentials for the purpose of my life.”
Government	“Without natural areas, gardens and trees, human life would be bereft. It is wicked that councils and governments are gradually usurping these areas that belong to everyone.” – Sydney respondent

Rejuvenation	“I would be really disappointed if the Westconnex freeway was approved and took away the wonderful green/bush reserve at Tempe Reserve. It is a haven for native life, and peaceful respite from the fast paced inner city.” – Sydney respondent
Safety	“Re: walking around etc, [there are] no options to discuss personal safety issues.” – Sydney respondent
Transport	“In the last 4 weeks I have given up a job that has been very stressful/toxic to my mental health, since I have been outdoors a lot and enjoyed getting closer to nature again with my areas for walking, it is truly a blessing to have these spaces, only a shame I need to drive.” – Auckland respondent
More detail about life situation	“I struggle with anxiety so though I love nature it doesn't really help me with my anxiety unfortunately it comes with me no matter where I am. I guess it's worse in a noisy shopping mall though than on a bush walk.” – Melbourne respondent

Survey Demographics

In a comparison with census data, the survey respondents were not representative of the population. The most significant difference concerned the highest level of education. The proportion of respondents with a postgraduate qualification (25-32%) was fivefold the proportion of the population with a postgraduate qualification (4-6%) (ABS 2011; Statistics New Zealand 2013). Females and participants who are married or in a de facto partnership were over-represented, and participants over 75 years of age were underrepresented in the survey (ABS 2011; Statistics New Zealand 2013). Most of the survey participants' households (22% over all four cities) comprised 2 adults and no children or pets.

A summary of fit of demographic elements of the three wellbeing indices (Online Resource 4) indicate some influence on responses. Gender and marital status affect personal wellbeing, with married respondents and women having higher personal wellbeing. Respondents in their late 40s and early 50s had higher personal wellbeing and general wellbeing (WHO-5) than other age groups. The

level of education had a positive effect on personal wellbeing. There were no significant interactions between relevant demographic measures and nature for all comparisons (Online Resource 5).

Discussion

Overall, our study suggested that nature in proximity to where people spend most of their time (for example, at home or work) and vegetation in their postcode are associated with respondents' wellbeing. Three wellbeing indices were used, but the strongest relationships with the wellbeing indices occurred in the Australian cities.

There were no significant associations between any of the measures of nature and wellbeing in Wellington. While it has been argued that there is low spatial variation between natural and non-natural spaces in New Zealand cities and that is a possible reason for New Zealand residents' wellbeing being less affected by nature exposure (Richardson et al. 2010), our GIS analysis demonstrates that the greatest variation in this study in vegetation occurs in Wellington (Figure 1). We suggest that the weaker patterns in the New Zealand cities is an artefact of the lower response rates in the New Zealand cities. This could be related to the smaller population of the New Zealand cities, particularly Wellington, when compared with the other cities in our study. However, that the number of respondents from each city represented a similar percentage of the total population of that city (between 0.01-0.02% of each city's population). Another possible explanation for the lower response rate in the New Zealand could be associated with Auckland and Wellington having fewer local councils than the Australian cities, thus reducing the possible publicization of our survey to those council's constituents.

While there were significant predictive relationships between some nature indicators and wellbeing, the R_2 values for these relationships were low. This indicates a need to tease out the reasons for the variation. Responses to the open question provided some detail that illustrated the nature of

respondents' reactions to nature in their cities and how they thought it affected their wellbeing. The qualitative comments of respondents from all four cities supported the significant quantitative findings of Melbourne and Sydney in relation to wellbeing. This could support that the weaker patterns in the New Zealand cities is associated with the lower response rate, rather than a different association between nature and wellbeing. Further research, particularly qualitative research, will explore the variation in patterns found between nature and wellbeing in the study cities.

Stress is a threat to the wellbeing of urban dwellers (Taylor and Hochuli 2015). While cities have benefits, such as the culture and energy of high density populations, stresses can have multiple effects on multiple aspects of our health (Dye 2008). Urban stress might include physical stressors such as pollution, noise, social stressors due to high density living, economic stressors, and the unrelenting stress of trying to balance work, family and personal lives (Sathyanarayana Rao and Indla 2010). These sorts of stresses were evident in the urban life dimension of the qualitative responses to the survey. Our findings are supported by a recent study that demonstrated via functional MRI scans that urban residents use a different part of their brains to process stress when compared with rural residents: the amygdala region of the brain, which is associated with fear and anxiety (Lederbogen et al. 2011). The dimensions of qualitative responses concerning wellbeing and nature were unsurprising because that was the focus of the survey. However, the dimension concerning urban life was unexpected because there was not a dedicated suite of questions on urban life that would have prompted thought in that regard. Of course, wellbeing and stress are inextricable, however the urban life dimension differed from wellbeing in that it involved being able to manage, prioritise, cope with, juggle or balance various aspects of urban life. The extra stress associated with urban areas and the stress caused by the balancing act respondents described in our study is what makes the urban life so challenging. We suggest that further investigation of urban stress and its mitigation is worth pursuing.

The urban life dimension suggested that respondents found some support when they encountered or sought out nature to help them cope with urban stresses. Nature represented a “peaceful respite from the fast-paced inner city” and “a great stress relief” and helped people “maintain balance”. Such comments support two areas of the greenspace and wellbeing literature in a way that the quantitative analysis was unable to: Attention Restoration Theory (Kaplan 1995), and stress recovery (Ulrich et al. 1991). Attention Restoration Theory posits that the multiple stimuli associated with urban environments can overwhelm us, whereas natural environments that conform to certain criteria can restore our cognitive capacity. Stress recovery and positive moods resulted more quickly and completely when participants were exposed to natural environments rather than urban environments (Ulrich et al. 1991). A number of studies have built on these findings when people look at or spend time in nature, for example, participants experience lower blood pressure and improved mood (such as Hartig et al. 2003), and nature sounds facilitate participants’ stress recovery (Alvarsson et al. 2010). While a number of respondents in our study recognised that they receive benefits when they spend time in nature, other studies suggest that an awareness of possible benefits is often underestimated (Nisbet and Zelenski 2011).

Wellbeing differs among nations (Diener et al. 2003) but the results of this survey suggest that in Australia and New Zealand, residents’ perceptions of their lives are not so different. General and personal wellbeing were similar across all four cities (Table 4). Both countries are similarly wealthy, and share very similar governance arrangements, development histories and cultural similarities. The wealth of the country, with its implications for longevity, human rights and equality, has been shown to impact wellbeing (Diener et al. 2003). Subjective Wellbeing Homeostasis theory suggests that severe variation of wellbeing is unlikely across similarly-developed nations (Cummins et al. 2003). While significant differences between general and personal wellbeing were not detected by the coarse measures we used, there is evidence that local nature is important. The differences in psychological wellbeing across cities support this (Table 4).

The lack of a consistent relationship between bird species richness and NDVI was unexpected, given previous studies (Bino et al. 2008). An explanation could be the coastal position of all study cities and inclusion of seabirds in the data; seabirds would interact less with terrestrial vegetation measured by NDVI. It could be that other measures should be considered, such as the amount and type of vegetation in a city rather than its vigour (e.g., Ikin et al. 2013). The bird species data have been published for use for research, such as identifying priority conservation areas (Jenkins et al. 2013) and to present the known distribution of identified species (Pimm et al. 2014). As more species richness data become more available (such as those at www.biodiversitymapping.org), we expect it to be worthwhile to repeat cross-country, multi-city studies such as this. This study potentially demonstrates that global ecological information is under developed (McDonnell et al. 2009), and highlights the need for further urban ecology work.

Due to the public and voluntary nature of the survey, respondents self-selected. This may have influenced the study results by portraying the perspectives of an unrepresentative demographic sample. Further research to seek input from under-represented groups, such as those without postgraduate qualifications and families, would complement the data presented in this study.

Conclusions

Wellbeing is supported by nature that is located in close proximity to where people spend their time (e.g., at home or at work) and within residents' postcodes. Residents from the two most populous cities of Australia and New Zealand responded in a consistent manner for general wellbeing (WHO-5) and personal wellbeing indices, suggesting similarities in general wellbeing across all four cities. Qualitative responses suggest that urban life presents a unique suite of stressors to residents. While the presence of nature in cities can support restoration from stress, further qualitative research would

provide detail about how respondents value nature and whether the frequency of their interactions with nature has an impact on their wellbeing.

There were differences in how the NDVI and bird species richness were distributed across the four cities, and differences in how psychological wellbeing was reported. How the differences in nature distribution affects psychological wellbeing in cities would be a useful topic for further research.

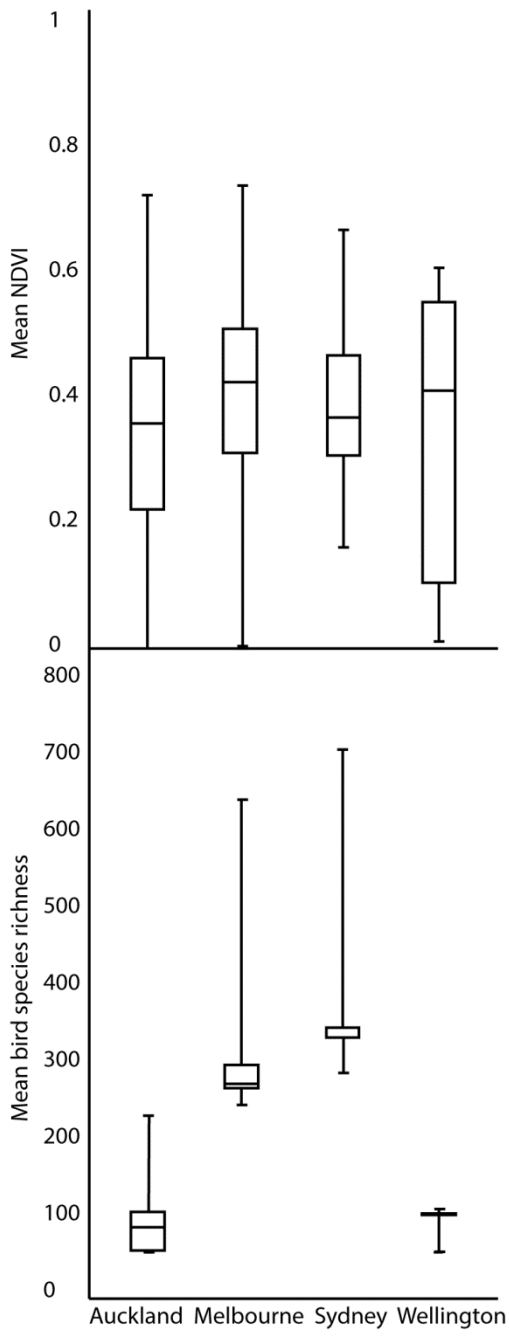
Nature is not the sole solution to urban stress, but our study suggests that is an important part of the balance that urban residents strive to keep.

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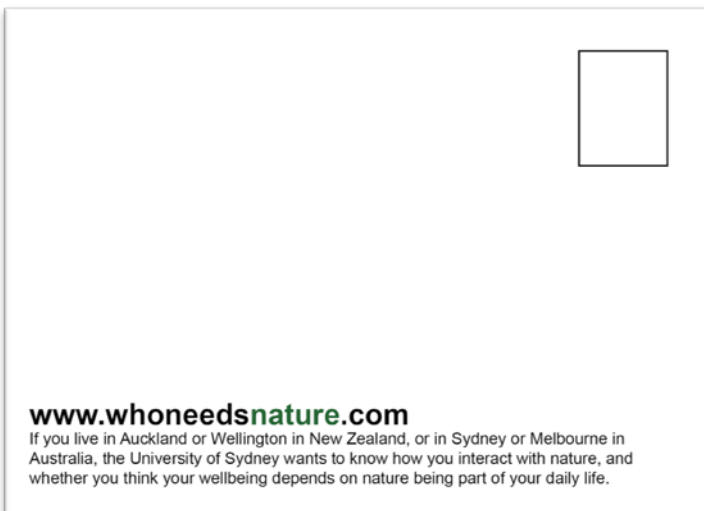
Online Resource 1. A comparison of the four study cities

The study cities represent the two most –populous cities of Australia (Melbourne and Sydney) and New Zealand (Auckland and Wellington) (ABS 2013; Statistics New Zealand 2006), yet they differ in scale, population, and biodiversity from each other.

	Population	Physical extent (Km²)	n. postcodes	Average responses per postcode	NDVI range	NDVI min-max	Bird species range	Bird species min-max
Auckland	1 303 068	1092.64	140	2.74	0.69	-0.003-0.689	166.75	65.25-232
Wellington	448 956	289.92	48	4.47	0.57	0.007-0.573	52.21	64.22-116.43
Melbourne	4 246 345	6571.84	384	3.47	0.29	0.001-0.294	374.14	245.86-620
Sydney	4 667 283	4502.3	400	4.60	0.12	0.151-0.269	397.89	284.11-682

Online Resource 2. Advertising

The advertising and postcards used a version of the first sentence from the media release, “If you live in Sydney or Melbourne in Australia, or Auckland or Wellington in New Zealand, the University of Sydney wants to know how you interact with nature, and whether you think your wellbeing depends on nature being part of your daily life.”



Online Resource 3. Principal components

We used principle components of each wellbeing item to create general wellbeing (WHO-5), personal wellbeing, and psychological wellbeing indices. The first principle component for each index loaded positively with all questions. The second principle components all explained less than 1 standardized unit of variance.

PCA component	PC1 % Variance	PC2 % Variance	Association with variables
Psychological wellbeing	60.7%	12.5%	
The reflection axis of Psychological wellbeing Cronbach alpha = 0.89	0.40	0.02	I feel peaceful when I go there
	0.41	-0.17	I gain perspective on life when I go there
	0.42	-0.07	Being there clears my head
	0.41	-0.08	Being there makes me feel more connected to nature
	0.37	-0.06	I can easily think about personal matters when I go there
	0.39	-0.12	When I am there I feel part of something that is greater than myself
	0.20	0.97	I do not feel calm when I am there (Reverse scored)
General wellbeing (WHO-5)	72.1%	9.3%	
WHO-5 Wellbeing Index Cronbach alpha = 0.90	0.47	-0.20	I have felt cheerful and in good spirits
	0.46	-0.41	I have felt calm and relaxed
	0.46	-0.14	I have felt active and vigorous
	0.44	-0.04	I woke up feeling fresh and rested
	0.42	0.88	My daily life has been filled with things that interest me
Personal wellbeing	50.7%	10.4%	
Based on the Personal Wellbeing Index Cronbach alpha = 0.86	0.38	-0.06	I am satisfied with my standard of living
	0.32	-0.08	I am satisfied with my physical health
	0.31	0.53	Generally, I feel safe
	0.30	0.57	I feel like part of my community
	0.36	0.23	I am satisfied with my future security
	0.38	-0.22	I am satisfied with my emotional wellbeing
	0.41	-0.34	I am satisfied with my life as a whole
	0.36	-0.41	I am satisfied with what I achieve in life

Online Resource 4. Wellbeing indices and demographic variables

We ran a general linear model looking at the way different demographic variables affected the wellbeing indices. Significant relationships are bolded.

Personal wellbeing index	Estimate	Std Error	t Ratio	Prob> t
Gender	0.171	0.077	2.22	0.027
18-24 age group	0.360	0.318	1.13	0.258
25-34 age group	0.054	0.209	0.26	0.798
35-44 age group	-0.183	0.211	-0.87	0.386
45-54 age group	0.640	0.246	2.60	0.010
55-64 age group	0.319	0.297	1.07	0.283
65+ age group	-0.146	0.692	-0.21	0.833
Marital status	-0.796	0.161	-4.94	<0.001
Household with children	0.033	0.077	0.43	0.664
Household with pets	-0.029	0.015	-1.94	0.053
Years at residence	0.046	0.050	0.93	0.354
Bedrooms at residence	0.016	0.010	1.58	0.114
Level of education (11 years or less of primary/secondary)	0.387	0.521	0.74	0.457
Level of education (completed highschool)	-0.318	0.345	-0.92	0.357
Level of education (certificate/diploma)	0.675	0.224	3.01	0.003
Level of education (bachelor degree)	-0.161	0.227	-0.71	0.479
Level of education (postgraduate degree)	0.473	0.214	2.21	0.027
English first language	-0.162	0.140	-1.16	0.246
General wellbeing (WHO-5) index	Estimate	Std Error	t Ratio	Prob> t
Gender	0.018	0.069	0.26	0.794
18-24 age group	0.250	0.285	0.88	0.382
25-34 age group	0.130	0.188	0.69	0.491
35-44 age group	0.094	0.191	0.49	0.621
45-54 age group	0.478	0.219	2.18	0.029
55-64 age group	0.237	0.265	0.90	0.371
65+ age group	0.585	0.625	0.94	0.350
Marital status	-0.259	0.145	-1.79	0.074
Household with children	-0.029	0.069	-0.42	0.671
Household with pets	0.011	0.014	0.77	0.440
Years at residence	-0.020	0.045	-0.44	0.657
Bedrooms at residence	0.002	0.009	0.24	0.813
Level of education (11 years or less of primary/secondary)	0.509	0.470	1.08	0.279
Level of education (completed highschool)	0.123	0.311	0.40	0.692
Level of education (certificate/diploma)	-0.091	0.201	-0.45	0.652
Level of education (bachelor degree)	0.276	0.205	1.35	0.178
Level of education (postgraduate degree)	0.271	0.192	1.41	0.159
English first language	-0.074	0.126	-0.59	0.558
Psychological wellbeing index	Estimate	Std Error	t Ratio	Prob> t
Gender	0.245	0.073	3.35	0.001
18-24 age group	0.461	0.302	1.53	0.127
25-34 age group	-0.304	0.198	-1.53	0.125
35-44 age group	0.102	0.202	0.50	0.614
45-54 age group	0.176	0.233	0.75	0.452
55-64 age group	-0.044	0.282	-0.16	0.876
65+ age group	0.034	0.687	0.05	0.961
Marital status	-0.100	0.153	-0.65	0.515
Household with children	0.130	0.073	1.77	0.077
Household with pets	-0.001	0.014	-0.11	0.915
Years at residence	-0.035	0.048	-0.74	0.459
Bedrooms at residence	0.002	0.010	0.23	0.819
Level of education (11 years or less of primary/secondary)	0.110	0.501	0.22	0.827
Level of education (completed highschool)	0.456	0.330	1.38	0.168
Level of education (certificate/diploma)	-0.234	0.213	-1.10	0.274
Level of education (bachelor degree)	0.271	0.218	1.25	0.213
Level of education (postgraduate degree)	-0.261	0.205	-1.27	0.204
English first language	-0.164	0.133	-1.24	0.217

Online Resource 5. Interactions between demographics and nature indicators

The demographic factors that had an effect on measures of wellbeing did not have a significant effect on the nature/wellbeing relationships. Significant results are bolded.

	Auckland	Melbourne	Sydney	Wellington
WHO-5				
NDVI*age	F(5,108)=1.66, p=0.150	F(6,550)=1.78, p=0.100	F(6,745)=0.81, p=0.559	F(5,52)=1.09, p=0.378
Birds*age	F(5,108)=1.74, p=0.133	F(6,543)=0.33, p=0.924	F(6,731)=1.56, p=0.156	F(5,52)=1.11, p=0.365
Nature home*age	F(5,102)=1.96, p=0.091	F(6,530)=1.96, p=0.069	F(6,710)=0.71, p=0.724	F(5,48)=0.57, p=0.724
Nature work*age	F(5,91)=0.94, p=0.462	F(6,498)=1.04, p=0.401	F(6,659)=0.56, p=0.766	F(4,48)=1.02, p=0.406
Personal wellbeing				
NDVI*gender	F(1,115)=0.94, p=0.335	F(1,555)=1.09, p=0.296	F(1,745)=0.26, p=0.610	F(1,60)=0.14, p=0.708
NDVI*marital status	F(1,114)=1.20, p=0.275	F(1,557)=1.45, p=0.230	F(1,746)=0.01, p=0.909	F(1,61)=6.40, p=0.014
NDVI*education	F(4,110)=3.10, p=0.019	F(5,549)=0.28, p=0.922	F(5,740)=1.08, p=0.368	F(4,55)=0.93, p=0.452
NDVI*age	F(5,107)=1.77, p=0.126	F(6,548)=0.61, p=0.726	F(6,739)=1.56, p=0.155	F(5,52)=1.22, p=0.312
Birds*gender	F(1,115)=4.29, p=0.041	F(1,548)=8.31, p=0.004	F(1,734)=0.01, p=0.911	F(1,60)=0.24, p=0.624
Birds *marital status	F(1,114)=0.01, p=0.939	F(1,550)=0.46, p=0.498	F(1,735)=1.04, p=0.307	F(1,61)=0.17, p=0.678
Birds *education	F(4,110)=0.52, p=0.722	F(5,542)=0.48, p=0.791	F(5,729)=0.29, p=0.919	F(4,55)=0.32, p=0.865
Birds*Age	F(5,107)=1.75, p=0.129	F(6,541)=0.71, p=0.644	F(6,728)=1.17, p=0.321	F(5,52)=0.85, p=0.523
Nature home*gender	F(1,110)=2.87, p=0.093	F(1,535)=0.16, p=0.693	F(1,711)=0.33, p=0.563	F(1,56)=1.03, p=0.314
Nature home*marital	F(1,108)=0.96, p=0.328	F(1,536)=0.85, p=0.357	F(1,712)=1.60, p=0.206	F(1,57)=0.16, p=0.689
Nature home*education	F(4,104)=0.13, p=0.972	F(5,528)=0.24, p=0.947	F(5,706)=0.36, p=0.878	F(4,51)=0.09, p=0.985
Nature home*age	F(5,101)=0.53, p=0.751	F(6,527)=0.92, p=0.483	F(6,705)=0.92, p=0.483	F(5,48)=1.68, p=0.157
Nature work *gender	F(1,97)=0.52, p=0.472	F(1,503)=2.22, p=0.137	F(1,660)=0.39, p=0.533	F(1,53)=1.33, p=0.254
Nature work*marital	F(1,97)=0.53, p=0.470	F(1,505)=5.44, p=0.020	F(1,660)=0.00, p=0.961	F(1,54)=0.09, p=0.771
Nature work*education	F(4,92)=1.45, p=0.224	F(5,497)=0.23, p=0.95	F(5,654)=0.89, p=0.487	F(4,48)=1.33, p=0.272
Nature work*age	F(5,90)=1.42, p=0.224	F(6,496)=1.16, p=0.325	F(6,653)=0.85, p=0.533	F(4,48)=1.17, p=0.338
Psychological wellbeing				
NDVI*gender	F(1,112)=0.46, p=0.501	F(1,549)=2.50, p=0.115	F(1,736)=0.24, p=0.623	F(1,58)=0.03, p=0.874
Birds*gender	F(1,112)=1.63, p=0.205	F(1,543)=0.53, p=0.465	F(1,722)=1.16, p=0.282	F(1,58)=0.38, p=0.538
Nature home*gender	F(1,107)=2.79, p=0.098	F(1,531)=1.25, p=0.264	F(1,702)=0.24, p=0.626	F(1,55)=0.41, p=0.524
Nature work*gender	F(1,95)=1.07, p=0.303	F(1,497)=0.32, p=0.569	F(1,651)=0.00, p=0.938	F(1,51)=0.52, p=0.475

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