Wildlife gardening: an urban nexus of social and ecological relationships

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Abstract

Biodiversity in urban environments continues to decline, alongside diminution of human connections with nature and community. An integrated ethic and practice of caring for one's human and ecological community could help address these issues. Here, we describe how wildlife gardening can be such a pathway. We snapshot related social dynamics and human wellbeing benefits, highlighting a case study that reveals an array of connections and wellbeing facets from wildlife gardening, and their relationship with number of activities and time spent in the garden. We outline how positive biodiversity outcomes can be attained through habitat improvement in gardens. We describe how integration of nature and human community stewardship can work across physical and political boundaries when government and communities work collaboratively. We argue that wildlife gardening carried out in this manner can involve urban residents in crafting and enacting an intertwined ethic and practice of caring for nature and humanity.

Introduction

Human wellbeing is inextricably linked with healthy nature in multiple ways and at multiple scales (Isbell *et al.* 2017). Interweaving values and responsible relationships for non-human species and natural entities (eg rivers) with those for humans is moral practice in many indigenous cultures (Gould *et al.* 2019). Such an approach is needed by societies globally to avert rapidly declining biodiversity and sustain human quality of life (Díaz *et al.* 2019). This entails looking beyond how we might receive wellbeing benefits from nature to considering how undertaking various acts of caring for nature can generate multiple forms of human wellbeing (Jax *et al.* 2018) and contribute to living a worthwhile life (Holland 2006).

Relationships between humans and the natural world encompass social, social–ecological, and ecological interactions that interweave across spatial and temporal scales (Liu *et al.* 2007). These are subject to uneven distributions of human power and governance (Avelino and Wittmayer 2016). Studies of these intertwined systems have generally occurred in natural resource management scenarios such as fisheries or forestry. We focus on the relationships surrounding urban residents and their gardens. We argue that these are of substantial importance given the increasing majority of people living in urban areas and the prominence of gardens and gardening.

Gardening is an ubiquitous relationship with nature, including in cities, that involves mind, senses, body and culture. Gardens are places of deep attachment and identity building, places for privacy and for forging social connections (Clayton 2007). An array of human wellbeing benefits derives from gardening in a diversity of cultural and garden settings. These include reduced depression, anxiety, and body mass index, as well as increased life satisfaction, quality of life, and sense of community (Soga *et al.* 2017).

The potential for gardening to contribute to biodiversity conservation is slowly gaining traction. A dearth of attention to this area in part arises from pervasive but mistaken beliefs that urban environments have little conservation value (Spotswood *et al.* 2021), and that urban residents lack the sense and type of place that engender biodiversity stewardship (Larson *et al.* 2015). Ecologically, the context for sustaining biodiversity in cities includes highly fragmented and modified land parcels under diverse ownership and management, numerous and culturally diverse human inhabitants, and novel combinations of local and introduced species (Aronson *et al.* 2017). Yards and gardens can comprise much of the green space of a city. Gardens with qualities that sustain particular species, including connectedness to other suitable habitat for those species, can collectively contribute to biodiversity conservation in urban environments (Goddard *et al.* 2010).

Gardening to attract wildlife probably has a history as long as gardening, but the promotion of gardening practices to improve habitat for native plant and animal species in cities began to appear in the 1970s (Adams and Leedy 1987). Gardening activities specifically aimed at sustaining locally native (henceforth indigenous) flora and fauna, including in company with non-native species, are called wildlife, habitat, ecological, wildscape, naturescape, or conservation gardening. These activities include planting indigenous species, removing invasive species, retaining mature trees and remnant vegetation, planting in layers from groundcover to canopy and adding habitat elements like water features and ponds (Figure 1). Some wildlife gardening initiatives purposefully seek to integrate connections and care for one's human community with connections and care for the indigenous species of the local landscape (eg Gardens for Wildlife Victoria 2021). In this they adopt principles of land stewardship as espoused by Aldo Leopold in his essay, The Land Ethic (Leopold 1949, pp 201-226). These principles extend the responsibility individuals have to cooperate with their human community to encompass "soils, waters, plants, and animals, or collectively: the land" (ibid p 204), affirming for indigenous species and landscapes the "right to continued existence, and at least in spots, their continued existence in a natural state" (ibid, p 204), within a context of human alteration, management and use of the land. We use the term wildlife gardening for this form of stewardship ethic and practice.

Despite wildlife gardening's importance, there remain substantial gaps in our understanding of its practice and potential across the social, ecological, and social–ecological domains. Here, we provide a snapshot of studies exploring the social dynamics and human wellbeing dimensions of wildlife gardening, and report empirical evidence of its positive effects on self-reported wellbeing and self-perceived increase in garden wildlife using a case study from Melbourne, Australia. We then review the direct and implied ecological benefits of wildlife gardening, including from a biodiversity conservation point of view. We finish by discussing the implications at the nexus of social–ecological inter-relationships, including how a stewardship ethic and practice might be fostered, across temporal, spatial, and governance boundaries.

Social dynamics and human wellbeing benefits

Qualitative studies of wildlife gardeners reveal that they derive features of wellbeing from wildlife gardening similar to those reported for other forms of gardening, such as making social connections, feeling reduced stress and anxiety and improved mood, and enjoying one's garden and nature, including experiencing living creatures and their interactions (Mumaw *et al.* 2017; Raymond *et al.* 2019; Diduck *et al.* 2020; Jones *et al.* 2021). Importantly, wildlife gardeners also express wellbeing benefits specifically associated with the stewardship intent of their gardening, including learning and sharing biodiversity stewardship skills and knowledge, and feeling a sense of purpose and contribution to helping wildlife and the environment (Mumaw *et al.* 2017; Raymond *et al.* 2019; Jones *et al.* 2021). Personal growth, purpose in life, and having positive relationships with others (termed eudemonic forms of wellbeing), are ascribed to living one's values and are believed to be as important as pleasurable experiences in contributing to qualify of life.

The pathways by which wildlife gardeners develop a land stewardship ethic and practice are influenced by multi-scalar social factors, such as cultural and neighborhood norms and behaviors, and institutional support (Diduck *et al*. 2020; Jones *et al*. 2021). Experiencing wellbeing, learning stewardship skills by doing, and connecting more strongly to nature, community and place appear to reinforce and strengthen stewardship values and practice in an interdependent way (Mumaw 2017). Participants in a wildlife gardening program run by a community–local government partnership were motivated by the visible involvement of both community members and local government staff, signaling to them that there was a credible municipal-wide effort to which their actions were contributing (Mumaw 2017). At a local government scale, a wildlife gardening program can strengthen an urban community's capacity to achieve conservation and human wellbeing outcomes by strengthening its collective social and ecological resources and their deployment in nature stewardship activities (Mumaw *et al*. 2019). When wildlife gardening initiatives are networked across local government boundaries, they have the potential to scale up – temporally, spatially, and in participant numbers, spread of associated values, and supportive institutional policies and priorities.

Results of the studies described above have yet to be explored quantitatively or comparatively in diverse social–ecological scenarios. To help fill this gap, we present a case study seeking to better understand wellbeing and wildlife observations derived from participating in a wildlife gardening program, and relationships with variables such as number of wildlife gardening activities undertaken and how often participants spent time in their gardens.

‘Knox Gardens for Wildlife’ case study

The Knox Gardens for Wildlife program (KG4W) is a partnership between Knox City Council (Greater Melbourne, Victoria, Australia), Knox Environment Society and the Knox community (Mumaw and Bekessy 2017). We evaluated responses to survey questions of program members to assess the effect of wildlife gardening on (1) self-reported dimensions of wellbeing, and (2) self-perceived increase in garden wildlife. We further examined whether these effects were related to demographic or property variables, how frequently respondents spent time in their gardens, and the number of wildlife gardening activities they undertook. We provide detailed descriptions of our data collection and modeling approach in Panel 1 and WebPanel 1.

The majority of respondents agreed that as a result of participating in the wildlife gardening program they felt dimensions of wellbeing associated with experiencing nature, self development (purpose, pride, learning), and connection/attachment to local nature, wildlife, place and community (Panel 1, Figure 2). This reinforces findings from previous qualitative wildlife gardening studies and highlights associations between connections to nature, diverse feelings of wellbeing, and attachment to place, which are increasingly being studied in human–nature interactions (Basu *et al.* 2020).

We found strong evidence for the positive effects of wildlife gardening on both self-reported wellbeing and self-perceived increase in garden wildlife. The number of wildlife gardening activities had a strong positive effect on both a wellbeing index (Figure 3a; WebPanel 1; WebTable 1) and perceived increase in wildlife index (Figure 3b; WebPanel 1; WebTable 1). In both cases, the effects were substantially stronger in participants who reported conducting four or more activities and spending time in their gardens on a daily basis (blue vs purple bands in Figures 3a,b). Our analyses did not reveal any statistical relationships between demographic or property variables and respondents’ reported wellbeing or perceived increase in garden wildlife. Our findings highlight the capacity of wildlife gardening to positively affect gardeners’ wellbeing and their perception of increases in wildlife in their gardens, and how these are mediated by the number of activities wildlife gardeners have undertaken – arguably a measure of wildlife gardening intensity – and how often they spend time in their gardens. Our findings also add weight for a model of stewardship development (Mumaw 2017) in which learning by doing, supported by rewarding results such as wellbeing, increases stewardship activities and connections to nature and place in an interlinked pattern of reinforcement.

Our findings provide a springboard for investigating relationships between the social and ecological impacts of wildlife gardening, an area that heretofore has received little attention. For example, are there associations between different wildlife gardening activities, the responses of different taxonomic and functional floral and faunal groups, and the gardening interests of wildlife gardeners? Can wildlife gardeners' observations be harnessed by citizen science and how would their observations compare to surveys by research scientists? How do diverse dimensions of human wellbeing and a city dweller's connections to people, nature and place relate to their personal attributes, the cultural and ecological contexts in which they are caring for nature, and experiential and temporal factors? How can we support a transformational change to embed an ethic and practice of nature stewardship in cities?

Ecological dynamics and biodiversity benefits

Evidence from observational and experimental studies is increasingly substantiating how practices associated with wildlife gardening lead to positive biodiversity outcomes. For example, indigenous plants, typically planted by wildlife gardeners, have been repeatedly demonstrated to outperform nonnative species in their capacity to provide food and habitat resources for insect taxa across a wide array of functional groups (Salisbury *et al.* 2017; Mata *et al.* 2021; Figure 1c). Suppressing highly invasive plant species, often ornamental exotics, allows a greater diversity of native plant species to be maintained, along with the arthropod fauna that rely on them (Garland and Wells 2020). Many threads of evidence show how it is possible to sustain and attract faunal biodiversity – from insect pollinators (Majewska and Altizer 2019) to native birds (Goddard *et al.* 2017) – through wildlife gardening practices such as providing nesting sites and water (Figure 1b), and creating dense layers of vegetation and leaf litter (Figure 1a). Providing suitable habitat features needed by diverse native species in gardens supplements the availability of habitat in other green spaces, helping to foster their conservation in cities (Ikin *et al*. 2015).

Advances in theoretical ecology can contribute to understanding the potential impacts of wildlife gardening on species composition and ecological structure across urban environments (Mata *et al*. 2020). For example, knowing which species play a key role linking and stabilizing ecological communities across different sites, such as pollinator species, can guide actions to support these species' persistence and that of their ecological networks (Hackett *et al*. 2019). Keystone species may be plants, as shown by Narango and colleagues (2020), in which a few plant species across the contiguous United States support a number of butterflies and moths whose caterpillars underpin numerous food webs.

Planting indigenous species in urban gardens – whether common, rare, threatened, or locally extinct – can effectively contribute to expand the range and potentially the genetic variability of the species meta-population (Hirst *et al*. 2019; Mata *et al.* 2020). Each wildlife garden acts as an in-situ conservation site, insuring against potential extinction events in the remainder of the population. Urban gardens have already been shown to successfully host threatened mammalian populations (Maclagan *et al*. 2018). Fostering and restoring indigenous species in urban environments both requires and facilitates an intimate understanding of how plant and animal species interact in space and time – a knowledge that helps, but is not sufficient alone, to underpin a broad based ethic and practice of urban nature stewardship.

Stewardship at the social–ecological nexus

It is at the nexus – the connection points – between myriad human, floral, faunal, and environmental interactions that nature stewardship has potential to support the wellbeing of diverse species and environments into the future. To facilitate nature stewardship from home gardens is to be cognizant of and work across and beyond boundaries –spatial, social, ecological, temporal – recognizing that many but not all are of human making, such as property or government borders, or perceived individual or collective responsibilities.

Getting community volunteers and local government to jointly and strategically boost biodiversity across their municipal landscapes – from gardens to streamsides, roadsides, and reserves – crosses spatial and social boundaries. Fostering keystone species, particularly those that link ecological networks across landscapes, crosses spatial and ecological boundaries. Biodiversity conservation strives to preserve nature into the future, attempting to cross temporal 'boundaries'. We are increasingly reminded that there are legacy effects on nature and people playing out today from human actions and environmental events that took place hundreds, thousands, or many more years ago. These range from extinction of species through urbanization to disruption of First Nation peoples' connections with the land through colonization.

A backbone of transformative change will be to understand urban populations (human and nonhuman) and environments as opportunities not threats, and to embrace new forms of governance. Amongst the most vexing questions are knowing who/what will be the 'winners' or 'losers', and how this will be decided. Our current view is that working collaboratively and inclusively, sharing knowledge and building on it through learning by doing, helps enable a community to iteratively develop solutions for sustaining biodiversity and human quality of life together. Wildlife gardening carried out in this context can involve a swathe of urban residents in crafting and enacting an intertwined ethic and practice of caring for nature and humanity.

Conclusions

Wildlife gardening provides opportunities for urban residents to sustain indigenous species amongst other flora and fauna, literally in their own backyards. Our wildlife gardening case study reinforces previous reports that wellbeing benefits derive from wildlife gardening, from enjoying nature to self-development and attachments to place and community. Participants reported seeing increasing numbers of wildlife and their observations could be harnessed by global citizen science initiatives such as iNaturalist and Birds in Backyards. Our findings highlight that stewardship intensity, wellbeing benefits, and connections to wildlife are mutually reinforcing. Investing in approaches that foster wildlife gardening will likely reap rewards in growth and depth of nature stewardship and a concurrent knitting of community connections and wellbeing. We advocate for local government authorities to work with their communities to set and achieve municipality-wide wellbeing and biodiversity objectives using wildlife gardening as a key strategy.

What seem familiar and minor acts of gardening play out in an array of social, ecological, and social–ecological relationships across neighborhoods and landscapes. Habitat changes in individual gardens can conserve indigenous biodiversity in connection with habitat availability and management in the region. Involvement of fellow citizens and local government agencies can strengthen community relationships through work towards common stewardship goals. We believe that wildlife gardening – accessible to most urban residents from balconies to backyards – offers entry to an intertwined relationship between place, nature, wellbeing, and a shared responsibility to community and the land. Wildlife gardening can help bring us closer to the cultures of First Nations Peoples, which have long been interwoven with the land and its indigenous life. Lastly, wildlife gardening programs across the world, adapted to the land and cultures in which they sit, may contribute to the achievement of global sustainable development goals, including those related to urban sustainability, human wellbeing and biodiversity.

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Panel 1: Data collection and modeling approach for the Knox Gardens for Wildlife case study

The survey was conducted by Knox City Council in 2016 and consisted of 20 questions of which we evaluated responses to 11 questions (WebPanel 1), including sections to capture participants' (1) demographics, (2) property characteristics, (3) perceived wellbeing and attachments as a result of wildlife gardening through the program, identified in an inductive study of a small sample of KG4W participants (Mumaw *et al*. 2017), (4) perceptions of wildlife increase since wildlife gardening, and (5) types of wildlife gardening activities. The survey was circulated via email on September 2, 2016 to approximately 85% of all members of the KG4W program (n=650). The survey took place over two weeks, during which approximately 30% (n=153) of program members provided responses that were included in the analysis.

We used the survey data to build two response variables: (1) a wellbeing index, to quantify the amount of self-reported wellbeing and attachments experienced as a result of participating in the KG4W program; and (2) a perceived increase in wildlife index, to assess whether respondents perceived an increase in the amount of wildlife present in their gardens since they began participating in the KG4W program. We developed the wellbeing index by mapping a five-point Likert scale (Q9 in WebPanel 1) – comprised of ten items specifically designed to capture multidimensional domains of wellbeing – to a continuous scalar ranging from -100 to 100 (WebPanel 1). To develop the perceived increase in wildlife index, we mapped participants' yes/no responses to the question "Since wildlife gardening, have you seen an increase of any wildlife in your garden?" (Q10 in WebPanel 1) as a probability (yes=1; no=0). A more detailed account of how these indices were constructed is given in WebPanel 1.

To draw inferences from the wellbeing and observed increased wildlife indices we followed a three-step approach (WebPanel 1). First, we developed a simple 'model of the mean' for each index to examine responses in the absence of explanatory covariates or factors. Next, we built individual models for each demographic and property factor (Qs 1-7) to examine their potential effects on the indices. A detailed account of these factors is included in WebPanel 1.

Finally, we expanded the models of the mean to include two explanatory variables hypothesized to drive a response in the wellbeing and observed increased wildlife indices: *number of wildlife gardening activities* (continuous, ranging from one to eight; WebPanel 1) and *time spent in garden* (categorical, either 'daily' or 'less than daily'). Details of wildlife gardening activities performed by respondents are also included in WebPanel 1.

We describe in detail our analytical approach, statistical models and Bayesian inference implementation in WebPanel 1.

Figure 1. Example of a wildlife garden and fauna associated with wildlife gardening practices. (top) A wildlife garden structured by multiple and dense layers of vegetation and leaf litter (Melbourne, Australia) R Kelly; (middle) providing water features contributes to support birds (here Allen's hummingbirds in Torrance, California) T Hall; and (bottom) the Austral stork's-bill Pelargonium australe, an indigenous species planted by wildlife gardeners in Melbourne, Australia, known to provide floral resources for a range of indigenous butterfly species, including the Australian painted lady Vanessa kershawi.

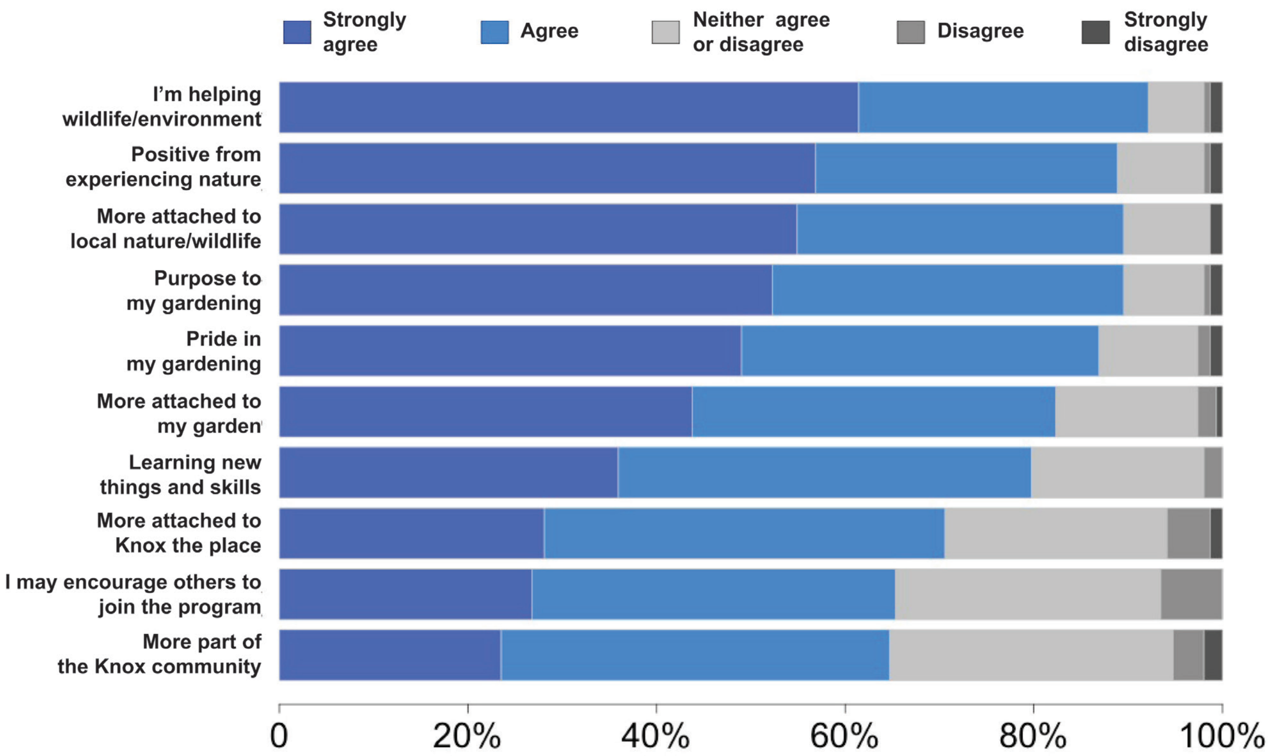

Figure 2. Respondents' agreement with feeling facets of wellbeing as a result of participating in the Knox Garden for Wildlife program.

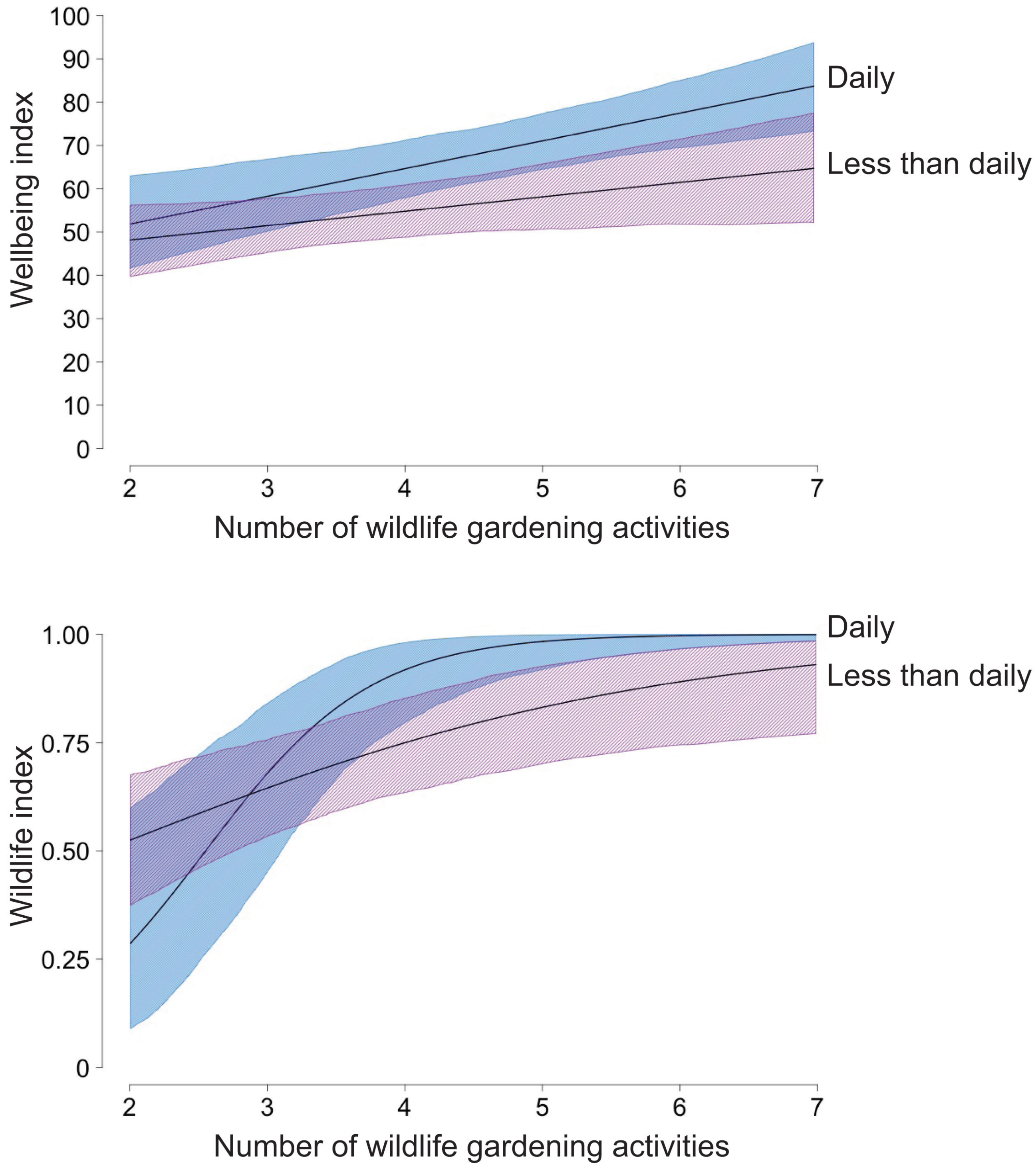

Figure 3. Response of the (top) wellbeing index and (bottom) perceived increase in wildlife index to the number of wildlife gardening activities and time spent in garden (daily vs less than daily). The black solid lines indicate the mean response and the shaded areas (blue = daily, purple = less than daily) represent the 95% credible intervals associated with each mean response.

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WebTable 1. Posterior estimates for the effects of number of wildlife gardening activities on self-reported wellbeing and perceived increase in garden wildlife, as mediated by how often wildlife gardeners spent time in their gardens

	Mean	**SD**	**CI: 2.5%**	**CI: 97.5%**
Self-reported wellbeing				
Daily				
Intercept	64.851	3.431	58.086	71.484
Slope	11.880	3.197	5.518	18.112
Less than daily				
Intercept	54.903	3.023	49.017	60.848
Slope	6.174	3.259	-0.306	12.564
Preceived increase in garden wildlife				
Daily				
Intercept	0.914	0.050	0.791	0.982
Slope	3.188	0.897	1.595	5.034
Less than daily				
Intercept	0.749	0.057	0.631	0.855
Slope	0.927	0.360	0.259	1.675

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WebPanel 1. Knox Gardens for Wildlife' case study: detailed descriptions of the data collection and modeling approach.

1. Survey questions used for analysis

Q1. What Postcode do you live in?

☐ 3153 ☐ 3156

☐ 3152 ☐ 3154

☐ 3155 ☐ 3179

☐ 3178

Q2. Were you born in Australia?

☐ Yes ☐ No

Q3. What is your age?

☐ 18-24 ☐ 25-34

☐ 35-44 ☐ 45-54

☐ 55-64 ☐ 65-74

☐ 75 or over

Q4. What best describes your household

☐ Couple with children ☐ Couple without children

☐ One parent family ☐ Group household

☐ Single person

Q5. What type of dwelling do you live in?

☐ unit ☐ apartment

☐ townhouse ☐ house

Q6. What is the environmental character of your property?

☐ new development (<5 yrs old)
☐ urban- suburban
☐ treed, natural surrounds
☐ apartment/ townhouse
☐ none of the above

Q7. How close are you to bushland?

☐ next door
☐ 5-10 min walk
☐ 10-20 min walk
☐ 20-30 min walk
☐ 30-60 min walk

Q8. How often do you spend time in your garden?

☐ everyday
☐ weekly
☐ fortnightly
☐ monthly
☐ quarterly
☐ other

Q9. As a result of participating in wildlife gardening through the Gardens for Wildlife program I…

Get positive feelings from experiencing nature

Am learning new things and developing new skills

Feel a sense of pride in my gardening

Feel a sense of purpose to my gardening

Feel that I am making a positive contribution to helping wildlife or their environment

Have encouraged other people to join the program

Feel more attached to my garden

Feel more attached to local nature and wildlife

Feel more attached to Knox the place

Feel more a part of the Knox community

5-point Likert scale:

Strongly disagree   Disagree   Neither agree nor disagree   Agree   Strongly agree

Q10. Since wildlife gardening, have you seen an increase of any wildlife in your garden?

☐ yes

☐ no

Q11. What wildlife gardening activities have you done since joining the program (tick all that apply)?

Removed environmental weeds

Planted indigenous species

Added water features

Keep/protect indigenous trees/regrowth

Put in nest boxes/hollows

Planted a prickly thicket

Put in lizard shelter

Put in frog bog/pond

2. Wellbeing and perceived increase in wildlife indices

Wildlife index

We developed the wellbeing index from a five-point Likert scale, which was specifically conceived to capture multidimensional domains of wellbeing:

The scale was designed around the question:

As a result of participating in wildlife gardening through the Gardens for Wildlife program I…

and comprised the following ten items:

Get positive feelings from experiencing nature

Am learning new things and developing new skills

Feel a sense of pride in my gardening

Feel a sense of purpose to my gardening

Feel that I am making a positive contribution to helping wildlife or their environment

Have encouraged other people to join the program

Feel more attached to my garden

Feel more attached to local nature and wildlife

Feel more attached to Knox the place

We used the following conversion table to map participants' responses to a continuous scalar ranging from -100 to 100:

Likert scale point	**Maps to:**
Strongly disagree	-10
Disagree	-5
Neither agree nor disagree	0
Agree	5
Strongly agree	10

The upper range of the index is therefore defined at 100, which is the case when a respondent assigns 'Strongly agree' to all ten items. Conversely, the index's lower range is defined at -100, which is the case when all ten items are scored as 'Strongly disagree'.

This mapping allowed us to generate an index that we could incorporate into our statistical models as a Gaussian-distributed response variable.

Our model of the mean indicated that in the absence of any explanatory variables the wellbeing index took a value of 59.62, with a 95% Credible Interval ranging from 54.90 to 64.36.

Perceived increase in wildlife index

We developed the wildlife index from the following Boolean-type question:

Since wildlife gardening, have you seen an increase of any wildlife in your garden?

We then mapped the responses as a probability, assigning the ‘Yes’ responses to 1 and the ‘No’ responses to 0.

This mapping allowed us to generate an index that we could incorporate into our statistical models as a Bernoulli-distributed response variable.

Our model of the mean indicated that in the absence of any explanatory variables the wildlife index took a value of 0.739, with a 95% Credible Interval ranging from 0.664 to 0.809.

3. Demographic and property variables

We developed individual models for each demographic and property factor (Survey question Q1-Q6) to examine their potential effects on the wellbeing and perceived increase in wildlife indices.

All six explanatory variables were treated as factors and introduced into the previously developed ‘model of the mean’ as fix effects:

Post code | 7 levels: 3152, 3153, 3154, 3155, 3156, 3178, 3179

Born in Australia | 2 levels: yes, no

Age | 7 levels: 18-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75+

Household | 5 levels: Couple with children, one parent family, single person, couple without children, group household

Dwelling | 4 levels: house, apartment, townhouse, unit

Distance to bushland | 5 levels: next door, 5-10 min, 10-12 min, 20-30 min, 30-60 min

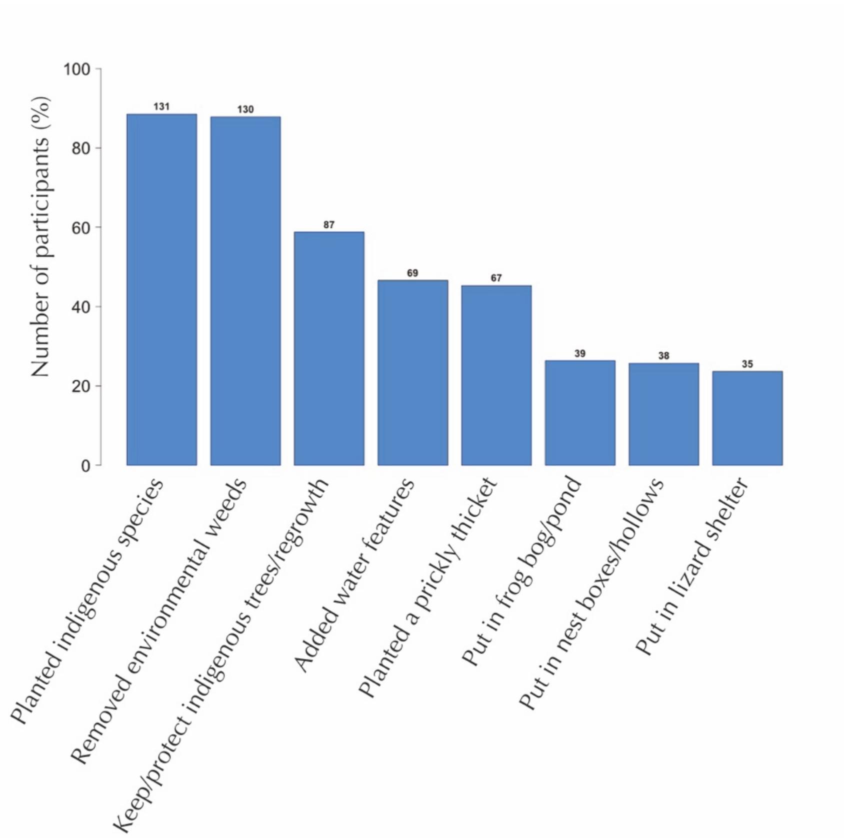
None of the 12 models (two indices times six explanatory variables) revealed any statistical differences amongst the tested fix effect groups.

4. Wildlife gardening activities and time spent in the garden variables

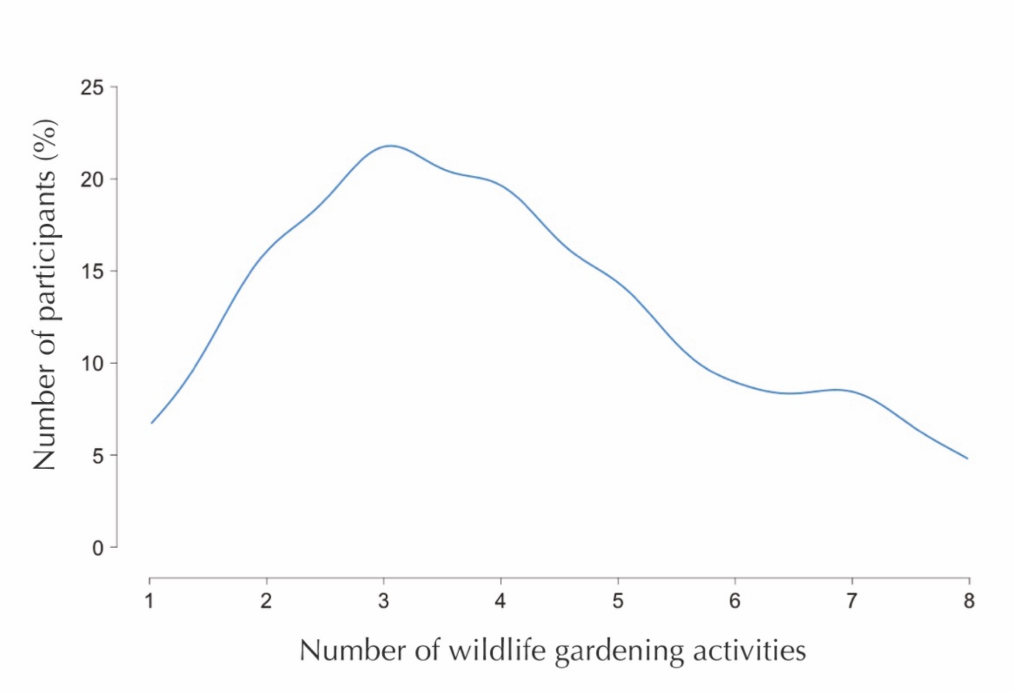
Number of wildlife gardening activities

We developed this explanatory variable from survey question Q10.

The figure to the right shows the ranked frequency distribution of the eight wildlife gardening activities. The numbers in bold on top of each bar summarises the total number of respondents that indicated conducting the given activity.



To generate the variable, we tallied the number of activities, which yielded a continuous variable ranging from one to eight. The figure below shows the distribution of the number of activities as a function of the number of participants.



Note that the number and type of wildlife gardening activities are influenced by garden characteristics and gardener capability and motivation, factors that were not explored here.

Time spent in garden

We developed this explanatory variable from survey question Q7. We conducted a series of exploratory analyses with this variable, introducing it as a factor in the previously developed 'model of the mean' for the wellbeing and perceived increase in wildlife indices. In our first model, the variable was coded as follow:

Daily: 1 | Weekly: 2 | Fortnightly: 3 | Monthly: 4 | Quarterly: 5

We note that 'other' was re-coded as one of the above levels when possible using information in the 'comment box'.

We found that the standard deviation for levels 4 and 5 were excessively large, as a consequence of their very low sample sizes. We therefore combined levels 3, 4 and 5 into single 'Less than weekly' group:

Daily: 1 | Weekly: 2 | Less than weekly: 3

The standard deviation of level 3 remained high, which lead us to combine levels 2 and 3 into a single 'Less than daily' group:

Daily: 1 | Less than daily: 2

This final model revealed similar low standard deviations for both levels. This general pattern was consistent across both indices. Therefore, we retained this two-level factorisation of the 'Time spent in garden' variable in our final models.

5. Statistical models and Bayesian inference implementation

To assess the effect of the *Number of wildlife gardening activities* and *Time spent in garden* explanatory variables on the wellbeing and perceived increase in wildlife indices, we analysed our data with a couple of closely related interaction-effects linear models (Kéry 2010).

We specified the wellbeing index models as:

$Well_i \sim \text{Normal}(\mu_i, \tau)$

and the wildlife index models as:

$Wild_i \sim \text{Bernoulli}(p_i)$

where $Well_i$ and $Wild_i$ are the wellbeing index and wildlife index, respectively, of participant *i.*

The linear predictor of the wellbeing model was specified as:

$\mu_i = a_{time\,i} + b_{time\,i} * nact_i$

and the linear predictor of the wildlife model was specified on the logit-probability scale as:

$\text{logit}(p_i) = a_{time\,i} + b_{time\,i} * nact_i$

where $a_{time\,i}$ and $b_{time\,i}$ are the intercept and slope effects, respectively, which were specified as:

$a_{time\,i} \sim \text{Normal}(0, 0.001)$

$b_{time\,i} \sim \text{Normal}(0, 0.001)$

and $time_i$ and $nact_i$ the values of the *Time spent in garden* and *Number of wildlife gardening activities* explanatory variables, respectively, for participant *i*.

In the wellbeing model, the precision (τ) is the reciprocal of the standard deviation:

$\tau = 1/\sigma^2$, which was specified as:

τ = Uniform (0, 100).

We estimated model parameters under Bayesian inference, using Markov Chain Monte Carlo (MCMC) simulations to draw samples from the parameters' posterior distributions. Our models were implemented in JAGS (Plummer 2003) and accessed through the R package *jagsUI* (Kellner 2016). We used three chains of 5,000 iterations, discarding the first 500 in each chain as burn-in. We visually inspected the MCMC chains and the values of the Gelman-Rubin statistic to verify acceptable convergence levels of R-hat < 1.1 (Gelman & Hill 2007).

References

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