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ORIGINAL PAPER

For the love of insects: gardening grows positive emotions (biophilia) towards invertebrates

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Abstract
As growing urban populations have fewer chances to experience nature, i.e., 'the extinction of experience', the subsequent loss of emotional affinities for biodiversity (biophilia) pose major challenges to environmental conservation. Gardening, as an everyday nature interaction and window into invertebrate ecological functioning may offer opportunities to develop biophilia. However, the associations between gardening and biophilia/biophobia towards invertebrates remains untested. We conducted an online survey (n = 443) with adults in Japan about their nature and gardening experiences, demographics, and species identification knowledge in relation to their biophilia (like) and biophobia (dislike, fear, and disgust) towards invertebrates. We also asked participants about their perceptions of invertebrates as 'beneficials' or 'pests'. From responses, we ranked invertebrates according to the attitudes held towards them. We found that frequent gardeners were more likely to express biophilia and perceive invertebrates as beneficial, and generally less likely to express biophobia towards invertebrates. Frequency of visits to recreational parks, but not national/state parks was associated with increased biophilia and reduced dislike and fear of invertebrates. Our results suggest that gardening, in addition to localised nature experiences, acts as a possible pathway towards appreciation of invertebrate biodiversity. We recommend that policymakers and conservation organisations view urban gardening as a potential tool to minimise the negative impacts of the extinction of experience.

Implications for insect conservation As people are more likely to conserve what they love, finding ways to nurture positive attitudes towards insects is critical for the public support needed for successful insect conservation. Considering gardening is a relatively accessible form of nature connection even in cities, our findings of the association between gardening and biophilia towards invertebrates holds promise for potential pathways towards fostering support for insect conservation now and into the future.

Keywords Biophilia · Biophobia · Extinction of Experience · Urban ecology · Gardening · Connection to nature

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Introduction

The last decade (2010–2020) has seen a massive decrease in the amount of time people spend interacting with nature, particularly for the global north (Soga and Gaston 2016). This ongoing, large-scale disconnection between humans and outdoor environments, or 'extinction of experience', is likely to be driven by the rapid urbanisation of human populations and the loss of natural environments and their associated biodiversity (Haaland & van Den Bosch 2015; Jim 2004), time constraints (Clements 2004; Hofferth 2009) and increased screen entertainment (e.g. video games). Although there remains debate as to its key drivers, the extinction of experience is increasingly recognised as a major challenge for biodiversity conservation worldwide (Miller 2005; Pyle 1978; Soga and Gaston 2016).

A key detrimental impact of the extinction of experience is the loss of people's positive, favourable emotions and attitudes towards wildlife (Wilson 1984), i.e. their emotional affinity to, interest in, and love of nature (see review by Soga and Gaston 2016). Consequently, the loss of direct interactions with nature can increase an individual's negative, unfavourable attitudes, such as fear and disgust towards wildlife, i.e. so-called 'biophobia' (Fukano and Soga 2021; Soga et al. 2020; Zhang et al. 2014). For the purposes of this study, we define biophilia and biophobia as people's positive and negative attitudes towards invertebrates, acknowledging that this does not cover the full biophilic concept.

Decreased biophilia, combined with increased biophobia, has negative implications for biodiversity conservation, and may lead to reduced motivations to protect wildlife and habitats (Johansson et al. 2012; Knight 2008; Schönfelder and Bogner 2017). As emotions towards biodiversity influence dependent children there is likely a feedback loop in which an increase of people with low biophilia/high biophobia in one generation, will result in an increase of people with similar attitudes in the next (Soga et al. 2020). As such, consequences of the extinction of experience could be long-term and widespread (Soga and Gaston 2016).

Both 'nearby' and 'wild' natural environments can play a key role in reducing the extinction of experience and its negative consequences (Soga et al. 2016). Indeed, there is mounting evidence that visiting national parks or urban greenspaces is associated with increased biophilia and decreased biophobia (Schlegel et al. 2015; Soga et al. 2020; Zhang et al. 2014), and that regular engagement with nature promotes pro-environmental attitudes and behaviours (Broom 2017). However, for urban dwellers, experiencing national parks or otherwise 'wilder' nature spaces can be challenging due to accessibility, time/financial constraints, and distance (Weber and Sultana 2013). Even in visiting local recreational parks, residents tend to be influenced more by their nature-orientation rather than proximity to greenspace (Lin et al. 2014). Hence combatting the extinction of experience involves both increasing opportunities and orientations to be in nature (Soga and Gaston 2016).

Gardening, as one of the most common activities in which people interact with nature, offers urban dwellers an accessible opportunity to experience nature. The growing of food and ornamentals is possible not only on farms, but in the densest of urban metropolises via balconies, rooftops, and backyards, as well as shared public land such as verges, parks, and community gardens (Lin et al. 2018). Consequently, gardens have become one of the main contexts for interactions with wildlife in urban areas (Goddard et al. 2013). As the majority of the world's populations now live in cities (WHO 2016), supporting urban residents to garden may increase the opportunity for nature interaction where there may otherwise be limited greenspace. Whilst 'time in nature' can motivate gardening, other incentives (e.g. growing food for consumption, social interaction, and leisure) that are not directly attached to wanting to be in nature means that gardening may create new orientations towards nature for those who may feel otherwise disconnected (Soga et al. 2017a, b). Qualitative studies have demonstrated that gardening confers benefits to wellness through immersion in nature (Soga et al. 2017a, b; Sonti and Svendsen 2018) and identified such immersion as one of the seven pathways to nature connectedness (Lumber et al. 2018). However, how and to what extent gardening influences people's biophilia and biophobia has not been tested empirically.

Attitudes towards wildlife including invertebrates are often used as metrics of biophilia and biophobia (Soga et al. 2018; Ulrich 1993; Zhang et al. 2014). As invertebrates (i.e. animals without backbones) comprise 80% of biodiversity and are common across all habitats including cities, certain charismatic species hold potential as flagships for connecting with urban nature (Schlegel and Rupf 2010). Furthermore, as invertebrates are entwined with humans, especially in food-growing ecosystems, gardeners are likely to encounter them regularly. For example, pollinators (e.g. bees) are fundamental to the success of many fruits and vegetables so gardeners may be likely to appreciate them (Lin et al. 2018). Gardeners may also experience increased contact with herbivorous 'pest' invertebrates (e.g., aphids) that can damage crops, as well as the natural enemies of such pests (e.g., ladybeetles). Hence gardeners may experience mixed emotions regarding the roles of invertebrates as beneficials and pests.

Feelings towards invertebrates can significantly impact their conservation as people are less likely to support conserving animals that they fear or are disgusted by, compared with charismatically 'cute' species (Cho and Lee 2017; Knight 2008; Prokop and Tunnicliffe 2010; Schlegel and Rupf 2010). Invertebrates are underrepresented in environmental education programs compared with large, charismatic mammals (Cho and Lee, 2017). Hence their low image, with few pathways for improvement, is a core issue to invertebrate conservation (Schlegel and Rupf 2010). As invertebrates are declining globally (Hallmann et al. 2017), biophobic attitudes towards them not only risks further disconnection from nature but poses direct threats to global ecosystem functioning and food security (Goulson et al. 2015; Klein et al. 2007).

Here, we ask whether time spent gardening, in nearby nature, and in national/state parks is affiliated with increased levels of biophilia towards invertebrates in Japan, one of the most urbanized countries in the world (OECD 2016). We conducted a web-based questionnaire survey (n = 443) among adults living in Japan. We investigated whether gardening is associated with: biophilia (like) or biophobia (dislike, fear, and disgust) towards invertebrates as well as perceptions of invertebrates as beneficial or pests. People's attitudes towards nature are commonly affected by various sociodemographic and lifestyle factors such as age (Bjerke and Østdahl 2004; Hosaka et al. 2017), gender (Hosaka et al. 2017; Schlegel et al. 2015; Schlegel and Rupf 2010), invertebrate identification ability (hereby 'knowledge'; (Schlegel et al. 2015; Schlegel and Rupf 2010; Soga et al. 2020; Zhang et al. 2014), exposure to nature at an early age, and frequency of outdoor activities (Schlegel et al. 2015; Soga et al. 2020). Thus, we adjusted for socioeconomic and lifestyle variables in our analyses to facilitate the detection of the effects of gardening as distinct from other potentially confounding factors.

Most studies investigating factors affecting biophilia/biophobia have been conducted with children, and data for adults is comparatively limited. We hypothesized that adults who spend more time either gardening, in (nearby) recreational parks, or in (wild) national/state parks would express greater emotional indicators of biophilia (like), less of biophobia (dislike, fear and disgust), would be more likely to perceive invertebrates as beneficial and less likely to perceive invertebrates as pests.

Methods

Questionnaire distribution

We conducted an online questionnaire of adults residing in Japan from July to November 2020. The questionnaire was written in Japanese. We distributed the questionnaire through social media (Facebook, Instagram and Twitter) through a small social-enterprise called "Sustainable Living Tokyo" and the lead researchers' personal accounts. Once in the public domain, our posts were subsequently shared via individuals and organisations mainly linked to sustainability in Japan. We also distributed flyers with a QR code link to the survey in public spaces, cafes, and live music venues. To encourage survey participation of the general public, we held a competition throughout the questionnaire period. Prizes were all related to sustainable living and were donated by small businesses in Japan. Ten respondents were randomly selected to win the prizes once the survey period ended. As such, our survey distribution was likely biased towards people who actively use social media and with at least some interest in sustainability, but not necessarily invertebrates, gardening or experiencing nature. We did not conduct a representative survey among the whole Japanese population because the aim of our study was not to estimate the magnitude of biophobia, but rather to investigate the relationship between multiple personal factors and biophobia.

Questionnaire

In the questionnaire we asked participants about their frequency and type of experiences in nature in recreational parks (i.e. nearby nature) as well as national/state/prefectural parks (i.e. wild nature), frequency and type of experiences gardening, invertebrate identification knowledge, attitudes towards invertebrates (biophilia/biophobia), and demographics (age, gender, education level).

Nature and gardening experience

In order to distinguish between nearby and wild nature experiences, we asked residents to report on nature-time spent in their neighbourhood (e.g. parks) vs. in prefectural parks. In Japan, national/state (i.e. prefectural) parks are often mountainous, or otherwise 'wilder' areas allowing for activities such as hiking, camping and fishing amongst others. Whilst not covering the full spectrum of 'wild' nature experiences possible, this metric aimed to cover most places in which residents of Japan would spend nature-time outside of urban, suburban and agricultural nature.

As such, to measure the frequency of nature experience in 'nearby' and 'wild' nature we asked participants:

> In the last year, how frequently have you visited natural places in your neighbourhood (e.g. parks).
> In the last year, how frequently have you visited prefectural parks?

Responses were recorded on a six-point Likert scale (1 = never, 2 = once a month, 3 = a few times a month, 4 = one or two times a week, 5 = three or four times a week, 6 = almost every day; Soga et al., 2020).

To measure frequency of gardening experience, we asked participants:

In the last year, how frequently have you gardened?

Responses were recorded on a five-point Likert scale (1 = never, 2 = once a month, 3 = once a week, 4 = more than once a week, 5 = every day; Soga et al. 2020).

Invertebrate identification knowledge

To estimate people's ability to identify invertebrates, as a proxy measure of 'invertebrate knowledge', we asked respondents "What do you generally call this invertebrate?" when presented with colour photographs of 16 invertebrates common to Japanese gardens (Fig. 1). Although subjective, the invertebrate images we selected were balanced for their associations as generally positive/beneficial and generally negative/pest species. We searched for images using common names, and chose representative species using the "creative commons" copyright license function in google.com. Respondents were able to freely write answers and/or leave the space blank. We classified answers as correct or incorrect to develop a score (0–16) for each participant used in analyses. We accepted common names to various taxonomic levels (e.g. "western honeybee", "honeybee" and "bee") while blank, incorrect, multiple answers which included an incorrect answer, and broad classifications of "invertebrate" and "larvae" were classified as incorrect. Two trained entomologists (including one native Japanese speaker) classified answers to invertebrate identification questions

Fig. 1 Invertebrates presented in the questionnaire. (1) Western honeybee *Apis mellifera,* (2) Cabbage butterfly larvae *Plutella xylostella,* (3) Slater *Armadillidium vulgare,*(4) Hoverfly *Myathropa florea*, (5) Cabbage butterfly adult *Plutella xylostella*, (6) Pumpkin beetle, *Aulacophora nigripennis,* (7) Giant hornet *Vespa mandarinia,* (8) Small bumble bee *Bombus ardens,* (9) Carpenter Bee *Xylocopa appendiculata,* (10) Slug *Arion rufus,* (11) Seven-spotted ladybeetle *Coccinella magnifica,* (12) Indian Fritillary *Argyreus hyperbius,* (13) Earthworm *Lumbricus terrestris,* (14) Yellowjacket wasp Vespula sp., (15) Aphids Family: Aphidoidea, (16) Brown marmorated stink bug *Halyomorpha halys*

independently, and then cross-referenced them to ensure responses were judged equally.

Biophilia/ Biophobia variables & invertebrate rankings

In order to assess biophilia and biophobia, we asked participants questions pertaining to 16 colour photographs of invertebrates common to Japanese gardens (Fig. 1);

1. *Which of these animals do you like?"* (biophilia)
2. *Which of these animals do you dislike?"* (dislike)
3. *Which of these animals are disgusting?"* (disgust)
4. *Which of these animals are scary?"* (fear)
5. *Which of these animals are beneficial?* (perceived beneficial)
6. *Which of these animals are pests?* (perceived pest)

Respondents answered by digitally ticking a grid for each invertebrate for each biophilia/biophobia variable (SI data 1). As such, it was possible for a respondent to both e.g. 'like' and 'dislike' an invertebrate. The minimum score for each variable was 0 and the maximum score was 16. We used the total number of species (0–16) selected for each question to calculate the biophilia/biophobia variables individually. As such biophobia variables of dislike, disgust and fear were assessed individually and not combined. Likewise, perceived pest and perceived beneficial were assessed individually. 'Like' was the only measure of biophilia used. These same scores for each variable (like, dislike, disgust, fear, perceived beneficial, perceived pest) were used to rank individual invertebrates from 1–16.

Statistical analyses

We used a maximum likelihood information-theoretic approach to address our overarching question of what kind of nature experiences influence attitudes towards invertebrates. We first fit separate negative binomial generalised linear models for each of the six dependent variables: biophilia (like), biophobia (fear, disgust, dislike), perceived beneficial, and perceived pest. We specified the same set of six predictors (all ordinal, spanning 0–16, save for gender) as main effects in each model. Three spoke directly to our hypotheses and included the frequency with which participant's gardened (gardening), the regularity with which they visited greenspaces in their neighbourhood (nearby nature), and the frequency with which they visited national or state parks (wild nature). Three further predictors, also drawn from our survey, are known to influence biophilia/biophobia based on our literature review. These were the demographic variables of age, gender, and education level. Finally, we included the metric of invertebrate identification knowledge as this is known to correlate with biophilia/biophobia (Schlegel and Rupf 2010; Zhang et al. 2014).

We mean-centred and standardised all predictors by dividing by their standard deviation for ease of interpretation and model selection, and visually verified all model assumptions (Quinn and Keough 2002) using the DHARMa package in R (Hartig 2021)**.** As our question was exploratory, we used a model selection and multi-model averaging procedure based on the adjusted Akaike's Information Criterion (AICc) (Burnham and Anderson 2002). We fit all possible main-effects subsets of the six global models, specified above, including an intercept-only null for each. We then retained all models within ΔAICc < 4 of the leading candidate and used the full weighted average of this set for inference (Burnham and Anderson 2002; Soga et al. 2020). In all models, we consider parameter estimates whose 95% confidence intervals do not overlap zero to be statistically significant. We used the R packages MASS (Venables, W. N., Ripley, 2002) for negative-binomial model fitting and MuMIn (Bartoń 2020) for information-theoretic model selection and averaging.

Results

Data Description

Of the 551 people who answered the survey, 443 responses were complete and used in analyses (see SI Data 2 for table of respondent demographics). Of the 443 respondents, 89% correctly identified at least one invertebrate, and 75% correctly identified half or more invertebrates (SI data 3). At least once a week, 49% of respondents gardened, 52% of respondents spent time in nature nearby (e.g. local parks), and 10% spent time in wild nature (e.g. national parks; SI data 3). At least once a month, 67% of respondents gardened, 84% of respondents spent time in nature nearby, and 34% spent time in wild nature (SI data 3). Overall, participants showed greater biophilia than biophobia towards invertebrates. Of the 443 respondents, 22% reported that they liked half or more of the 16 common garden invertebrates (SI data 4). Of the 443 respondents, 11% disliked, 9% feared and 8% were disgusted by at least half of the invertebrates (SI data 4). Furthermore, 18% of respondents perceived at least half of invertebrates as beneficial while 3% perceived at least half of the invertebrates as pests (SI data 4).

Invertebrate rankings

Ladybeetles (*Coccinella magnifica*) were the most 'liked' invertebrates (14% of participants) followed by western honeybees (*Apis mellifera*, 11%) and (adult) cabbage butterflies (*Plutella xylostella*, 11%; SI data 4). Stink bugs

(*Halyomorpha halys*) were the most 'disliked' invertebrates (14%) followed by aphids (Aphidoidea, 11%) and slugs (Arionidae, 11%; SI data 4). The most feared invertebrates were giant hornets (*Vespa mandarinia*, 23%), followed by yellow jacket wasps (15%), carpenter bees (*Xylocopa appendiculata*, 8%), bumblebees (*Bombus ardens,* 8%), hoverflies (*Myathropa florea*, 8%) and western honeybees (8%; SI data 4). Slugs (17%), followed by aphids (14%), stink bugs (12%) and earth worms (12%) were seen with the greatest disgust (SI data 4). Honeybees (15%) and earthworms (*Lumbricus terrestris*, 15%) were perceived as the most beneficial invertebrates (SI data 4). Cabbage butterfly larvae (14%), aphids (14%), slugs (13%), and stink bugs (12%) were perceived the most as pests (SI data 4).

What kinds of nature experiences predict biophilia/biophobia?

Biophilia (like)

Gardening experience, time spent in nearby nature, and identification knowledge were all significantly, positively associated with biophilia (Fig. 2a; Table 1). There were no significant correlations between biophilia and wild nature, education, age, or gender. The averaged model included all variables with an R^2 range of 0.108—0.121 (SI data 5).

Biophobia

Disgust toward invertebrates The time respondents spent gardening and in nearby nature were both significantly negatively predictive of disgust (Table 1, Fig. 2b). Younger respondents were significantly more likely to be disgusted by invertebrates than older (Table 1, Fig. 2b). The time people spent in wild nature, their identification knowledge, and their level of education had no significant correlations with disgust (Table 1, Fig. 2b). The averaged model included all variables with an R^2 range of 0.118–0.130 (SI data 5).

Dislike toward invertebrates Only time spent in nearby nature was significantly negatively associated with dislike, with no effects of other independent variables (Table 1, Fig. 2). Whilst non- significant, time spent gardening, in wild nature and education level demonstrated weak negative associations with dislike. The final averaged model was similarly weak, and included all variables with an R^2 range of 0.069–0.090 (SI data 5).

Fear toward invertebrate Time spent gardening and in nearby nature were both significantly negatively associated with fear of invertebrates (Table 1, Fig. 2b). Younger respondents and females were also more likely to fear invertebrates in comparison with older respondents and males respectively (Table 1, Fig. 2b). The averaged model included all variables with an R^2 range of 0.179–0.190 (SI data 5).

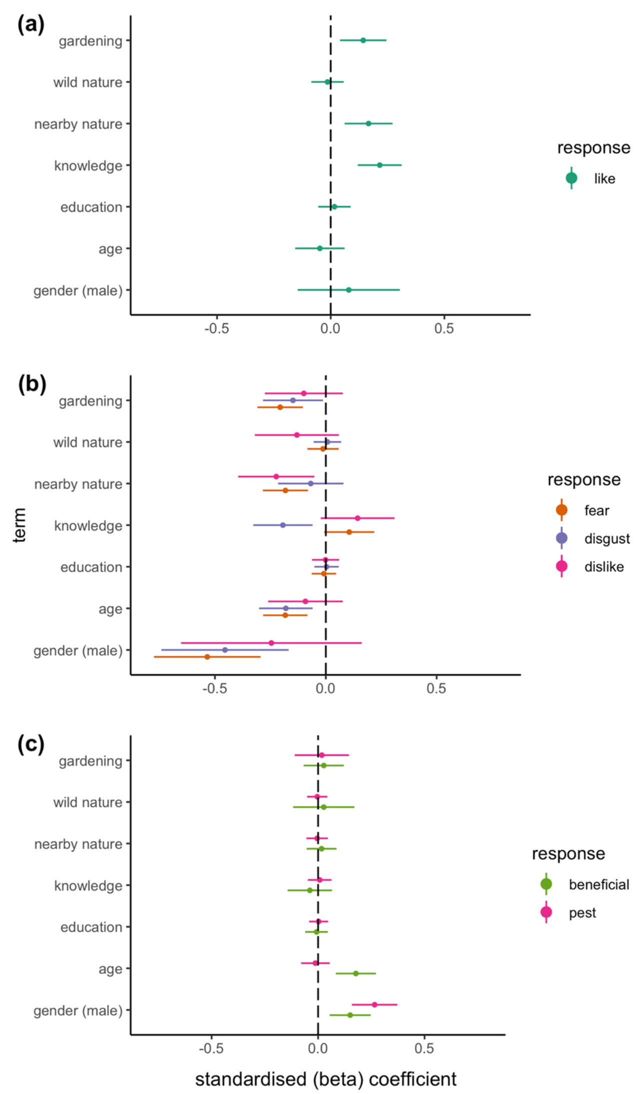

Fig. 2 Standardised and mean-centred parameter estimates from negative-binomial generalised linear models describing respondents' **a** Biophilia (like), **b** Biophobia [disgust, dislike, fear], **c** Perception of invertebrates as beneficial and as pests. Each model specified the same set of six main effects, comprising three experiential [frequency of gardening, time in local parks (nearby nature), and national/state parks (wild nature)] and four demographic (identification knowledge of common invertebrates, level of education, age, and gender) measures. All response variables and predictors, save for gender, are ordinal measures (0–16), as estimated via an online survey with 443 complete responses. Note that the presented estimates represent weighted model averages following information-theoretic model selection (see "Methods" for full details). Points and lines denote ± 95% CI's, respectively, with estimates considered significant when intervals do not encompass 0.

Table 1 Standardised and mean-centred parameter estimates from negative-binomial generalised linear models describing the attitudes of participants toward invertebrates across six measures

	Estimate	Std. error	z value	Pr(>|z|)	RVI
Like					
Intercept	1.426	0.055	25.879	**0.000**	
Gardening	0.143	0.052	2.743	**0.006**	0.94
Nearby nature	0.166	0.054	3.093	**0.002**	0.98
Wild nature	– 0.014	0.036	0.385	0.701	0.32
Knowledge	0.216	0.049	4.369	**0.000**	1.00
Education	0.017	0.036	0.455	0.649	037
Age	– 0.048	0.055	0.860	0.390	0.57
Gender (male)	0.080	0.115	0.694	0.488	0.48
Disgust					
Intercept	1.051	0.065	16.087	**0.000**	
Gardening	– 0.148	0.069	2.145	**0.032**	0.89
Nearby nature	– 0.194	0.068	2.839	**0.005**	0.94
Wild nature	– 0.068	0.075	0.901	0.368	0.61
Knowledge	0.007	0.032	0.227	0.821	0.28
Education	0.003	0.028	0.111	0.911	0.27
Age	– 0.180	0.061	2.933	**0.003**	0.97
Gender (male)	– 0.455	0.146	3.107	**0.002**	0.97
Dislike					
Intercept	1.061	0.082	12.914	**0.000**	
Gardening	– 0.099	0.090	1.105	0.269	0.67
Nearby nature	– 0.224	0.087	2.552	**0.011**	0.93
Wild nature	– 0.130	0.097	1.350	0.177	0.75
Knowledge	0.144	0.085	1.691	0.091	0.78
Education	– 0.001	0.031	0.037	0.970	0.27
Age	– 0.092	0.086	1.070	0.285	0.65
Gender (male)	– 0.246	0.208	1.181	0.238	0.70
Fear					
Intercept	1.142	0.053	21.406	**0.000**	
Gardening	– 0.206	0.052	3.940	**0.000**	1.00
Nearby nature	– 0.182	0.052	3.506	**0.000**	0.99
Wild nature	– 0.013	0.036	0.352	0.725	0.33
Knowledge	0.105	0.058	1.826	0.068	0.82
Education	– 0.009	0.028	0.303	0.762	0.30
Age	– 0.183	0.051	3.584	**0.000**	0.99
Gender (male)	– 0.534	0.122	4.356	**0.000**	1.00
Beneficial					
Intercept	1.483	0.049	29.953	**0.000**	
Gardening	0.151	0.049	3.060	**0.002**	0.97
Nearby nature	0.027	0.048	0.555	0.579	0.44
Wild nature	– 0.039	0.053	0.728	0.467	0.50
Knowledge	0.177	0.048	3.692	**0.000**	1.00
Education	0.016	0.036	0.461	0.645	0.38
Age	– 0.007	0.027	0.259	0.795	0.30
Gender (male)	0.027	0.073	0.363	0.717	0.33
Pest					
Intercept	0.721	0.053	13.481	**0.000**	
Gardening	0.008	0.028	0.268	0.788	0.32
Nearby nature	– 0.004	0.026	0.173	0.863	0.28
Wild nature	– 0.013	0.034	0.371	0.710	0.36
Knowledge	0.265	0.054	4.880	**0.000**	1.00
Education	0.002	0.023	0.108	0.914	0.27
Age	– 0.004	0.024	0.167	0.868	0.29
Gender (male)	0.018	0.065	0.270	0.787	0.32

Each model specified the same set of six main effects, comprising three experiential [frequency of gardening, time in local parks (nearby nature), and national/state parks (wild nature)] and four demographic (identification knowledge of common invertebrates, level of education, age, and gender) measures. Significant values are highlighted in bold text. *RVI* denotes the relative variable importance, estimated as the sum of Akaike weights of all models (from the averaged set) in which a given variable appears. All response variables and predictors, save for gender, are ordinal measures (0–16), as estimated via an online survey with 443 complete responses. Note that the presented estimates represent weighted model averages following information-theoretic model selection (see Methods for full details)

Perceptions of invertebrates

Beneficial Gardeners and those with greater invertebrate identification knowledge were more likely to perceive invertebrates as beneficial (Table 1, Fig. 2c). No other measured variables showed significant correlations (Table 1, Fig. 2c). The final averaged model which included all variables was relatively weak, with an R^2 range of 0.057–0.069 (SI data 5).

Pest Respondents with greater identification knowledge were more likely to perceive invertebrates as pests (Table 1, Fig. 2c). No other measured variables significantly correlated with perceptions of invertebrates as pests. The final averaged model which included all variables was relatively weak, with an R^2 range of 0.054–0.057 (SI data 5).

Discussion

As people have fewer chances to experience nature in increasingly concreted cities, a subsequent loss of biophilic attitudes is of great concern for environmental conservation (Soga et al. 2016, 2020). Gardening, as one of the most common ways people can experience nature even in cities, offers an opportunity for re-connecting urban people with biodiversity (Lin et al. 2018). To our knowledge, our study is the first to show that frequent gardeners are more biophilic and generally less biophobic towards invertebrates. Whilst in this study we cannot disregard the possibility that people garden because they are biophilic, our results confirm that gardening as a practise is indeed associated with positive attitudes towards invertebrates and thus has potential to rekindle positive associations between people and the natural world.

The importance of gardening and urban nature

The perception of invertebrates as beneficial, but not as pests, was more common amongst frequent gardeners but not necessarily in respondents who otherwise frequently spent time in nature. As gardeners are faced with the challenges and opportunities presented by herbivorous invertebrates (e.g. damaging crops) as well as the beneficial ecosystem services provided by predatory and pollinating invertebrates, frequent gardeners are likely to learn the ecological roles of particular invertebrates through direct experience. Additionally, gardeners may be initially motivated to garden for reasons that are not directly linked to a love of biodiversity, such as growing food that is culturally appropriate, less costly than buying or no/low chemical input, and for leisure, aesthetics and/or therapeutic ends (Sonti and Svendsen 2018). Hence gardening as a pathway to biophilia combines the benefits of (1) contact with invertebrates simply through being outside amongst them (Soga et al. 2019), (2) directly experiencing a functional understanding of their ecological role in relationship with ornamental/food crops grown in gardens (Lin et al. 2018), and (3) introducing people who wouldn't otherwise intentionally spend time in nature to a new way to do so. Our findings hence support recommendations to increase gardening programs, gardening education, and equitable access to gardening space to address the 'opportunity' (access) and 'orientation' (motivation) issues associated with the extinction of experience, and consequently improve biophilic attitudes overall (Lin et al. 2018).

That time spent in natural greenspaces improves biophilia and reduces biophobia is well supported in the literature (Schlegel et al. 2015; Soga et al. 2016, 2020). However, despite experience in nearby nature being associated with greater biophilia and decreased biophobia, experience in wild nature had little to no influence on the measured variables in our study. Whist it may be surprising that not all outdoor nature experiences are predictive of biophilia, our findings affirm the growing appreciation of urban greenspaces as important for nature connectedness in an increasingly urban population (Soga and Gaston 2016).

The idea that 'wild' nature 'out there' is the only nature worth perceiving as natural has been debated for generations (Cronon 1996; Nash 1967). With the caveat that even the most remote of natural areas have been managed by Indigenous peoples for generations (Kimmerer and Lake 2001; Pascoe 2018), such 'wild' nature is not always accessible or sustainable to get to for urban dwellers. For those who live in cities it can be a privilege to be able to visit a national park, requiring physical ability, time, transport, and finances (Weber and Sultana 2013**)**. Unsurprisingly then, those who live closer to national parks are more likely to visit then those who live further away (Weber and Sultana 2013). Indeed, in our study, we found that respondents were twice as likely to garden and/or visit nearby nature spaces then they were to visit national/state parks.

This is consistent with work from New Zealand, where children were significantly more likely to spend time in their immediate home gardens, despite biodiverse greenspace availability in their neighbourhood, likely due to reasons of perceived safety (Hand et al. 2017). Whilst the conservation value of national parks is irreplaceable, our results are promising in that they confirm that nearby nature experiences can contribute to improving biophilic and reducing biophobic attitudes. By bringing "nature to people, rather than people to nature" we may contribute to minimizing inequitable impacts of the extinction of experience for people in cities (Lin et al. 2018).

Urban landscape design plays a significant role in the extinction of experience (Colléony et al. 2017). Models of 'land-sharing' (extensive development over a large area, hence greater 'sharing' of greenspace between humans and wildlife) as opposed to 'land-sparing' (intensive development within a small area) can contribute to reducing the extinction of experience by fostering incidental interactions with invertebrates (Soga et al. 2015). Whilst land sparing in a dense city has been shown to promote greater beetle diversity (Soga et al. 2014), the interconnected matrix of greenspaces in cities such as gardens, verges, rooftops, parks, sporting fields, cemeteries and schools, can also act as 'refuges' for insect biodiversity (Hall et al. 2017). Hence designing and increasing public urban spaces for insect biodiversity is important not only to conserve said biodiversity directly, but also to enable access to those who spend time only in 'nearby (urban) nature' (Soga et al. 2015). However, as affluent areas have public and private greenspaces of greater and better quality, access to nearby nature, and hence the potential for incidental invertebrate interactions, is marked by socio-economic injustice (Rigolon 2017; Shanahan et al. 2014). Under these circumstances, residents of low-income urban neighbourhoods may be at greater risk of developing biophobic attitudes as caused by the extinction of experience (Rigolon 2017). Addressing this inequity involves providing more high- quality parks and even public spaces to grow food, such as community and allotment gardens. In doing so, people may access the wellbeing benefits of gardening (Soga et al. 2017a, b), whilst developing biophilic attitudes in those who may otherwise be at greater risk of feeling disconnected from nature.

The role of other personal factors

Our study supports findings that younger adults are generally more biophobic than older adults, at least for metrics of fear and disgust (Bjerke and Østdahl 2004; Hosaka et al. 2017). This pattern may be explained by older generations having spent more time in nature as children and is consistent with the extinction of experience hypothesis (Hughes et al. 2019; Soga and Gaston 2016).

Liking and disliking invertebrates was not associated with gender in our study. Rather, it was outdoor experiences and identification ability that explained peoples' perceptions of invertebrates. However, males were less fearful and disgusted by invertebrates; a finding supported in the wider literature (Hosaka et al. 2017; Schlegel et al. 2015; Schlegel and Rupf 2010). The cumulative impacts from childhood of gendered socialization whereby males are expected to be 'unafraid', and females to be 'disgusted' by invertebrates may contribute to explaining this pattern and is consistent across many cultures (Davey et al. 1998).

Our finding that invertebrate identification knowledge was predictive of biophilia is consistent with most studies in this area (Schlegel et al. 2015; Schlegel and Rupf 2010; Soga et al. 2020; Zhang et al. 2014). However, despite a generally negative correlation between biophobia and identification knowledge in the literature, we found no such significant associations (Schlegel et al. 2015; Schlegel and Rupf 2010; Soga et al. 2020; Zhang et al. 2014).

Perceptions of invertebrates as beneficial/pests are metrics that combine emotions towards them, with an understanding of their ecological functioning. With the caveat that all invertebrates are somehow involved in the ecological food web, the invertebrate images chosen were equally balanced for generally 'useful' and 'damaging' species from the perspective of crop production. We found that people with greater identification knowledge were more likely to perceive invertebrates as beneficial. They were also more likely to perceive invertebrates as pests. Hence considering beneficial/pest insects from an integrated pest management approach were equalised, these findings emphasise that the ability to identify the invertebrate in question will influence either the 'emotion', perceived 'usefulness' or a combination. This is particularly relevant for gardeners who may react to known herbivore species (e.g. aphids) that eat their crops, as well as known predatory species (e.g. wasps) that control these populations. However, although we measured knowledge as invertebrate identification ability, this is but one metric which does not take into account culinary, cultural and ecological knowledge of invertebrates, which have been found to be important to describing peoples' relationship with invertebrates (Costa-Neto and Dunkel 2016).

Attitudes towards different invertebrate species

Not only knowledge, but the ease of recognisability, direct childhood experiences, how invertebrates are approached in school curricula, and cultural associations all play important roles in people's invertebrate preferences (Prokop and Tunnicliffe 2010). The predatory 7-spotted lady beetle as the most liked invertebrate in our study is consistent with the cultural positivity held for ladybeetles in Japan (Katayama and Baba 2020). The ladybeetle pictured is a common, charismatic species which is easily recognisable from its bright red spotted figure (Fig. 1). The Japanese primary school curriculum includes ladybeetles as model species to explain the beneficial role of predatory insects (Iwama et al. 2008). This role makes them useful to gardeners as they feed on the herbivorous invertebrates who may damage crops. Hence although we did not test this directly, it is likely that the combination of direct contact and benefit in the garden, charismatic recognisability, childhood education, and cultural associations all contributed to the ladybeetle emerging as a favourite.

That the (adult) cabbage butterfly was the second most liked invertebrate is consistent with studies finding that butterflies are favourited invertebrates for their aesthetic appeal (Schlegel et al. 2015; Shipley and Bixler 2017). Such perceptions contribute to disproportionate representation of butterflies and moths in invertebrate conservation and education, leaving less charismatic, less 'likeable' invertebrates off conservation lists and policy agendas (Berenbaum 2008). In a gardening context, larval cabbage butterflies are a common herbivore of brassicas such as broccoli, but adults are beneficial pollinators as adults. Despite this, they did not rank highly as either beneficial or pest species. More influential perhaps is that cabbage butterflies are commonly seen and associated with the start of spring in Japan. Furthermore, primary school students learn about cabbage butterflies as model species for insect morphology and lifecycles (Iwama et al. 2008). Cabbage butterflies thus hold aesthetic and cultural significance, recognisability, introduction from an early age, and a high likelihood for regular direct experience; all factors which contribute to greater biophilia.

Socio-cultural norms also likely played a role in stink bugs ranking highly in terms of dislike and disgust, despite not being particularly feared. Throughout Japan, an abundance of stink bugs will find their way into people's homes each autumn, searching for an overwintering site. As their name suggests, stink bugs release a 'foul odour' as a defence mechanism (Waterhouse et al. 1961). The combination of 'stink' and 'plague-like' bouts of large numbers in the home likely bring up senses of invasion of private space, ideal conditions for high levels of disgust and dislike, similar to other domestic pests such as cockroaches (Wagler and Wagler 2021). Slugs and aphids reproduce in similar bouts, suddenly appearing in large numbers in the garden, and also ranked highly in terms of disgust. When designing environmental education programs related to invertebrates, it is important to acknowledge these innate socio-ecological-cultural associations, and find creative ways to shift them through positive experiences (Wagler and Wagler 2013).

Attitudes towards Hymenopteran insects (i.e. bees and wasps) and their mimics (i.e. hoverflies) were a mix of both love and fear as expected from the literature (Sumner et al. 2018). The bees and hoverfly were greatly liked, but bees, hoverflies and wasps were also highly feared likely due to fear of stings (Cho and Lee 2017; Schlegel et al. 2015; Sumner et al. 2018). Although hoverflies are harmless, they are often mistaken for bees due to their similar colouration (pers. comms). Honeybees are often loved for their association with honey, and appreciation for their vital pollinating roles are increasing in the eyes of the public (Sumner et al. 2018). Hence the high ranking of hoverflies may be that people recognise and appreciate them intrinsically, or more likely, due to their being mistaken for honeybees (see SI data Table 3; Silva and Minor 2017). Whilst more people are recognising the importance of honeybees (Sumner et al. 2018), the role of solitary bees, wasps and flies as vital pollinators remains underestimated (Smith and Saunders 2016). Opportunities for direct interaction and education on their ecological roles could help with combatting fears of stings, and in turn help to grow biophilic attitudes towards these pollinators (Cho and Lee 2017). As insect pollination is critical for many fruits and vegetables grown in home gardens, direct experiences through gardening may increase the likelihood of appreciating pollinators in particular and is worth pursuing in intervention studies.

Limitations and future directions

Evidently, the six measures of biophilia and biophobia we used are likely to be interrelated in multiple ways. An individual's levels of like towards invertebrates, for example, is likely to be negatively associated with those of dislike and disgust. Fear and danger are also likely to be closely related, as the latter might be, at least partly, the driver of the former. It should be noted, however, that measures of biophilia and those of biophobia are not always negatively related. Indeed, positive attitudes towards wildlife can exist even for feared animals such as bears (Kaczensky et al. 2004). Further studies focusing on diverse animal species are needed to fully understand how biophilia and biophobia are related.

In our study we found significant associations between gardening, nearby nature and biophilia/biophobia, however we cannot determine direction or causality from our approach. A logical extension of our research would be to measure whether gardening experiential interventions can in fact shift biophilic/biophobic attitudes in adults. Furthermore, we did not examine how the quality of gardening activities and nature experiences influences biophilia and biophobia. Evidently, the quality, as well as the quantity, of an individual's experiences varies substantially among people, and this can affect their attitudes towards invertebrates. It would therefore be beneficial to determine the relative importance of quantity and quality of gardening and nature experiences, as well as their interactions, in shaping people's biophilia and biophobia. Including a direct measure of orientation towards nature (i.e. nature connectedness) would also help disentangle whether gardening acts to increase orientation and/or access to nature.

As our study included potential bias through respondents' self-reported perceptions of invertebrates and frequency of nature experiences, further studies using more objective measures may deepen our understandings. Our recruitment protocol was biased towards social media users interested in sustainability, hence expanding our research with different populations may prove valuable. Expanding our survey to include countries other than Japan may also prove interesting to assess the cultural and contextual differences on the role of gardening and biophilia/biophobia.

Conclusions and recommendations

We found that biophilia increases with gardening experience and time spent in nearby nature. Whilst we cannot here unravel whether gardeners are inherently more biophilic, or whether biophilia grows with gardening, our results suggest that gardening has the potential to minimise the impacts of the extinction of experience, as the practise is associated with positive attitudes towards invertebrates. Given that forging and reinforcing people's positive perceptions of wildlife is crucial for building broad-based public support for biodiversity conservation (Sumner et al. 2018), urban gardening, from a long-term perspective, may have substantial positive outcomes for the future of biodiversity worldwide. As such, policymakers and conservation organisations should view urban gardening as an opportunity for conservation education. Indeed, since many gardens require relatively small pieces of land, creating new or expanding existing gardens may be achieved rapidly and at relatively low cost even in densely populated areas like Japan. Viewing the potential of gardening to grow both opportunity and orientation towards nature, may be a useful pathway to combatting the negative effects of biophobia as associated with the extinction of experience.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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