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Cross-generational decline in childhood experiences of neighborhood flowering plants in Japan

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ABSTRACT

People are becoming less likely to experience nature, as we become an increasingly urban society. This progressive disengagement of humans from the natural world, "extinction of experience", has been viewed both as a key public health issue and one of the most fundamental obstacles to halting global environmental degradation. However, while the existence and significance of the phenomenon are generally agreed upon, it remains surprisingly poorly documented, particularly at large scales and over the longer-term. Here, we report the findings from a web-based questionnaire survey (n = 1147) to assess the extent of people's childhood experiences with neighborhood flowering, plants, one of the most popular and visible group of organisms, in Japan. Results showed that people's levels of childhood experiences with neighborhood flowering plants were positively related to their age: older participants, compared to younger ones, reported higher frequencies of childhood experiences with neighborhood flowering plants. The reported number of neighborhood flowering plant species that participants have directly experienced during childhood was also higher for older participants. Among the 21 flowering plant species we investigated, age-related decline in direct experiences during childhood was observed for 9 species, particularly for those that depend on grasslands (an ecosystem that has been in dramatic decline over the last few decades). Participants' age and childhood environment (urban vs. rural settings) also had significant effects on their levels of childhood nature experiences. Overall, our results suggest that children's direct connection to neighborhood biodiversity is indeed progressively dwindling, which can have serious implications for public health and biodiversity conservation.

1. Introduction

It is widely held that over recent decades more and more people worldwide, and especially children, have been interacting less and less with natural environments and their associated biodiversity (Skar, Wold, Gundersen, & O'Brien, 2016; Skår & Krogh, 2009; Soga & Gaston, 2016). This progressive alienation of humans from the natural world, so-called "extinction of experience" (Miller, 2005; Pyle, 1993), is cause for concern for two reasons. First, those who do not directly interact with nature are likely to lose substantial health benefits. Indeed, researchers have documented a wide range of health and well-being benefits associated with regular contact with nature (Hartig, Mitchell, De Vries, & Frumkin, 2014; Keniger, Gaston, Irvine, & Fuller, 2013), and multiple theories have been formulated to explain the positive human response to the natural world, including biophilia (an innate, human evolutionary affinity for other living organisms and processes; Wilson, 1984), stress reduction theory (Ulrich et al., 1991), and attention restoration theory (Kaplan, 1995). Second, extinction of experience can discourage people's positive emotions, attitudes, and behavior toward nature, implying a cycle of disaffection toward the natural world (Soga & Gaston, 2016). It is well-known that people's appreciation of the value of the natural world, motivation to protect nature, and willingness to participate in pro-environmental activities are influenced strongly by the frequency of their direct experiences of nature in everyday surroundings (e.g., Soga, Gaston, Koyanagi, Kurisu, & Hanaki, 2016; Soga, Gaston, Yamaura, Kurisu, & Hanaki, 2016; Wells & Lekies, 2006; Zhang, Goodale, & Chen, 2014).

While the existence, prevalence and significance of extinction of experience is widely agreed upon (Colléony, Prévot, Saint Jalme, & Clayton, 2017; Miller, 2005; Soga & Gaston, 2016), it remains surprisingly poorly documented. This is particularly true over large spatial scales and longer periods. Indeed, the majority of the existing studies and case reports assessing changes in people's levels of direct experiences with nature have been based on data from relatively small

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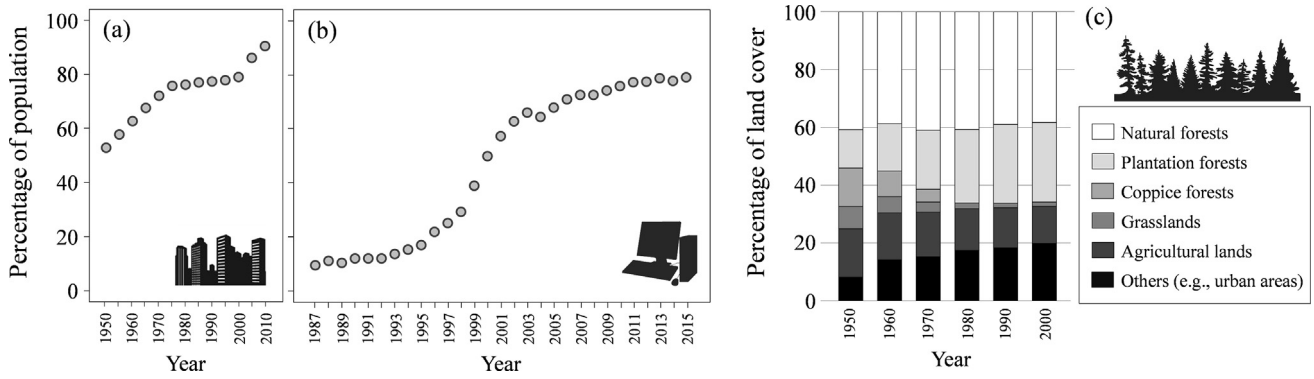

Fig. 1. Decadal changes in the proportion of people (a) living in urban areas and (b) having a personal computer, and in (c) land cover in Japan. Data from (a) the United Nations (2014), (b) the Cabinet Office, Government of Japan (2017), and (c) Yamaura et al. (2012).

regional or local-scale surveys (see Soga & Gaston, 2016). Also, previous studies have commonly used comparison of data sets obtained from two relatively short-time intervals (e.g., Clements, 2004; England Hofferth, 2009; Marketing, 2009), making it difficult to determine whether any reported decline in people's direct experience with nature represents a short-term fluctuation or an emerging long-term trend (note: a notable exception is work on the decline in national park visitation; Balmford et al., 2009; Pergams & Zaradic, 2008). Furthermore, we know little about the extent to which levels of direct interaction with neighborhood biodiversity (plants and animals that can be seen in people's everyday surroundings) have changed over time, as previous work has typically focused on the frequency of visiting "natural environments" or participation in "outdoor play" (Soga & Gaston, 2016).

Japan provides an interesting opportunity for studying changes in the relationship between people and nature. On the one hand, this country has a traditional culture with a notable appreciation for nature, and especially for wild flowering plants (Saito, 1985). On the other hand, there are many potential drivers that might lead to an extinction of experience (Fig. 1). First, as in many developed countries, Japan has experienced rapid growth in the urban population over the last few decades, with more than 90% of the people today living in cities and towns (Fig. 1a). Compared with most European and North American small- or medium-sized cities, Japanese cities are generally built at a higher density, with local greenspaces being smaller and more scarce (OECD, 2016). It is therefore likely that today much of the Japanese population has little, if any, opportunity directly to experience nature. Second, the increased use of screen-based media (e.g., TV viewing, internet use, playing video games) has resulted in increased levels of sedentary behavior among people in Japan (Fig. 1b), which is likely to reduce their motivation to participate in nature-based activities (Clements, 2004; Pergams & Zaradic, 2006). Third, over the past few decades, land use and land cover in Japan have changed substantially. One of the notable changes is the dramatic loss of semi-natural landscapes, such as grasslands and coppice forests, which have declined by more than 90% over the last 50 years (Suka, Okamoto, & Ushimaru, 2012; Yamaura, Oka, Taki, Ozaki, & Tanaka, 2012) (Fig. 1c). These environments were maintained through traditional agricultural and forestry practices, but after the 1950s they gradually disappeared, mainly due to the introduction of new fuels and intensive agricultural practices (Yamaura et al., 2012). As a consequence, many plant and animal species that were once commonly seen in neighborhood environments are today in serious decline or facing extinction (Koyanagi & Furukawa, 2013; Nakamura, 2011; Suka et al., 2012). This nationwide loss of neighborhood natural ecosystems and their associated biodiversity is likely markedly to alter the form of human-biodiversity interactions.

There are two main approaches to determining the existence of extinction of experience. The first, and arguably more straightforward, is to collect time-series data on people's levels of interaction with nature, and examine the temporal trends (see Balmford et al., 2009; Pergams & Zaradic, 2008). Unfortunately, however, reliable historical data are usually very scarce, and if they exist they are fragmentary, often making this approach impractical. The second approach is to undertake a retrospective survey (i.e., an assessment where the investigators ask subjects to recall events that happened earlier in their lives), a widely used research technique in social science (Batcho, Nave, & DaRin, 2011; Modestino & Winchester, 2013). Self-reported surveys of this kind are likely the only available approach for probing many dimensions of the extinction of experience. However, inevitably they have limitations, particularly centered on the accuracy with which participants can recall past events (Coughlin, 1990), although these may be reduced by careful survey design and execution.

Here, we report the results of a questionnaire survey of 1147 Japanese people, designed to assess the extent of people's childhood experiences with neighborhood flowering plants, one of the most popular and visible group of organisms. The primary goal of our study is to assess whether, and if so the extent to which, there are age-related declines in people's frequency and intensity of childhood experience with neighborhood flowering plants (the latter measured by the number of flowering plant species directly experienced during childhood). We also examined how people's gender and childhood environment (places where they have spent most of their childhood) affect their childhood experiences of nature. Specifically, we investigated whether the extent of the age-related decline in people's childhood experiences with neighborhood flowering plants differ by gender and childhood environment.

2. Methods

2.1. Ethics clearance

This research was approved by the research ethics committee at the University of Tokyo (no. Agr-17-007). Participants completed a digital consent form prior to beginning the questionnaire. Participants were told they would remain anonymous, and were given the option of declining involvement.

2.2. Participants and questionnaires

The survey was performed in late January 2017. Participants were recruited using a market research company (Nikkei Research Inc.), identified from their consumer database to meet the study inclusion criteria. In order to minimize interference stemming from major cultural and socio-economic differences, participants who live in remote rural areas (i.e., islands except for the four major islands of Japan) were excluded from the study. All questionnaires were completed remotely via web-based forms. The questionnaire asked about three topics: (1) frequency and (2) intensity of childhood experiences with

neighborhood flowering plants and (3) socio-demographics. We targeted enrollment of 1000 survey participants to ensure sufficient representation of socio-demographic diversity in the survey sample. After two weeks, the targeted number was achieved (n = 1147) and the survey was terminated on 5 February 2017.

2.3. Frequency of childhood experiences with neighborhood flowering plants

To measure participants' frequency of childhood experiences with neighborhood flowering plants, they were asked three questions: 1) "How frequently did you visit neighborhood natural places (e.g., urban parks, woodlands, grasslands) during childhood?"; 2) "How frequently did you observe/touch neighborhood flowering plants in neighborhood natural places during childhood?"; and 3) "How frequently did you observe/touch neighborhood flowering plants in your domestic garden during childhood?". To avoid confusion, we clearly defined the term "childhood" as aged from 6 to 12 years. Responses were scored on a six-point scale (1 = never; 2 = approximately every year; 3 = approximately every six months; 4 = approximately every month; 5 = approximately every week; 6 = approximately every day).

2.4. Intensity of childhood experiences with neighborhood flowering plants

To measure participants' intensity of childhood experiences with neighborhood flowering plants, part of the questionnaire presented color photographs of 21 common wild flowering plant species, and they were asked to select those that they had directly experienced (observed closely or touched) during their childhood. Specifically, for each plant species, we asked participants: "Did you observe closely or touch during your childhood?" We adopted this approach rather than asking participants to list and name as many plant species as they encountered during childhood (Lindemann-Matthies, 2002), because the latter seems to depend strongly on their cognitive ability and motivation to participate in the survey. We chose a diverse array of flowering plant species, with reference to the list of Japanese wild flowers (Miyawaki, Okuda, & Mochizuki, 1978; Satake, Hara, Watari, & Tominari, 1982) and consultation with experts with specialist knowledge on wild flowers in Japan. These species comprised *Trifolium repens*, *Erigeron philadelphicus*, *Astragalus sinicus*, *Cirsium japonicum*, *Capsella bursa-pastoris*, *Viola grypoceras* var. *grypoceras*, *Vicia sativa* subsp. *nigra*, *Dianthus superbus* var. *longicalycinus*, *Stellaria neglecta*, *Lamium amplexicaule*, *Lamium purpureum*, *Geranium thunbergii*, *Eupatorium japonicum*, *Sisyrinchium rosulatum*, *Anemone flaccida*, *Glechoma hederacea* subsp. *grandis*, *Corydalis incisa*, *Persicaria senticosa*, *Polygonum thunbergii*, *Eranthis pinnatifida*, and *Eclipta thermalis* (Table 1). These 21 species occur across a wide range of natural environments that people can visit daily, including roadside verges, domestic gardens, farmlands, meadows, grasslands, secondary forests, and riverside, and none of them requires specific types of habitats that people are unlikely to have access to in their daily lives (e.g., alpine conditions). The number of plant species experienced, ranging from 0 to 21, was used as a measure of the intensity of childhood experience with neighborhood flowering plants.

With reference to the literature (Miyawaki et al., 1978; Satake et al., 1982), the 21 common wild flowering plant species were classified into three species groups according to their preferred habitat types: 11 roadside, 7 grassland-farmland, and 3 woodland species (Table 1).

2.5. Socio-demographics

Participants were asked to provide information on their age (1 = 20 s; 2 = 30 s; 3 = 40 s; 4 = 50 s; 5 = 60 s; 6 = 70 s), gender (female; male), and childhood environment (places where participants have spent most of their childhood). The responses to childhood environment were recorded in three categories: urban areas, suburban areas, and rural areas. In this study we defined the term urban, suburban and rural areas respectively as a human settlement with high population density and built environment infrastructure, a residential district located on the outskirts of a city, and an area outside of cities and towns (with plenty of natural environment). Demographic statistics of respondents are summarized in Table S1.

Table 1
List of the 21 neighborhood flowering plant species included in the questionnaire.

Scientific name	Habitat type	Number and proportion of participants who had direct experiences	
		n	%
Trifolium repens	Roadside	756	65.9
Erigeron philadelphicus	Roadside	553	48.2
Astragalus sinicus	Grass/ farmland	543	47.3
Cirsium japonicum	Grass/ farmland	453	39.5
Capsella bursa-pastoris	Roadside	443	38.6
Viola grypoceras var. grypoceras	Roadside	367	32.0
Vicia sativa subsp. nigra	Roadside	360	31.4
Dianthus superbus var. longicalycinus	Grass/ farmland	303	26.4
Stellaria neglecta	Grass/ farmland	230	20.1
Lamium amplexicaule	Roadside	188	16.4
Lamium purpureum	Roadside	133	11.6
Geranium thunbergii	Roadside	112	9.8
Eupatorium japonicum	Grass/ farmland	96	8.4
Sisyrinchium rosulatum	Roadside	82	7.1
Anemone flaccida	Woodland	74	6.5
Glechoma hederacea subsp. grandis	Roadside	74	6.5
Corydalis incisa	Woodland	73	6.4
Persicaria senticosa	Roadside	42	3.7
Polygonum thunbergii	Grass/ farmland	36	3.1
Eranthis pinnatifida	Woodland	27	2.4
Eclipta thermalis	Grass/ farmland	22	1.9

2.6. Statistical analysis

2.6.1. Frequency and intensity of childhood experiences with neighborhood flowering plants

We analyzed the data to detect whether a participant's age, gender and/or childhood environment were related to their frequency and intensity of childhood experiences with neighborhood flowering plants. Ordinal logit regression models were used for the frequency measure, and generalized linear models (GLMs) for the intensity measure. To fit these models we used the "clm" function (with a proportional odds logit link function) within the "ordinal" package (ver. 2015.6–28) (Christensen, 2015) and the "glm" function (with a log-link and a Poisson error distribution) in R (ver. 3.2.5) (R Core Team, 2015). For the frequency measure, the answer to each of three questions was used as a response variable after all categorical answers were ordered. For the intensity measure, the reported number of plant species, among the 21 study plant species, that were experienced in childhood was used as a response variable (0–21 species). As explanatory variables, a participant's age, gender and childhood environment were used. We also tested interaction terms between age and gender and between age and childhood environment to examine whether the extent of the age-related decline in people's childhood experiences with nature differ by gender and childhood environment. Since our preliminary analysis showed no significant interactions between gender and childhood environment, we did not include their interaction term in the model. Gender and childhood environment were treated as categorical explanatory variables, and female (gender) and urban areas (childhood

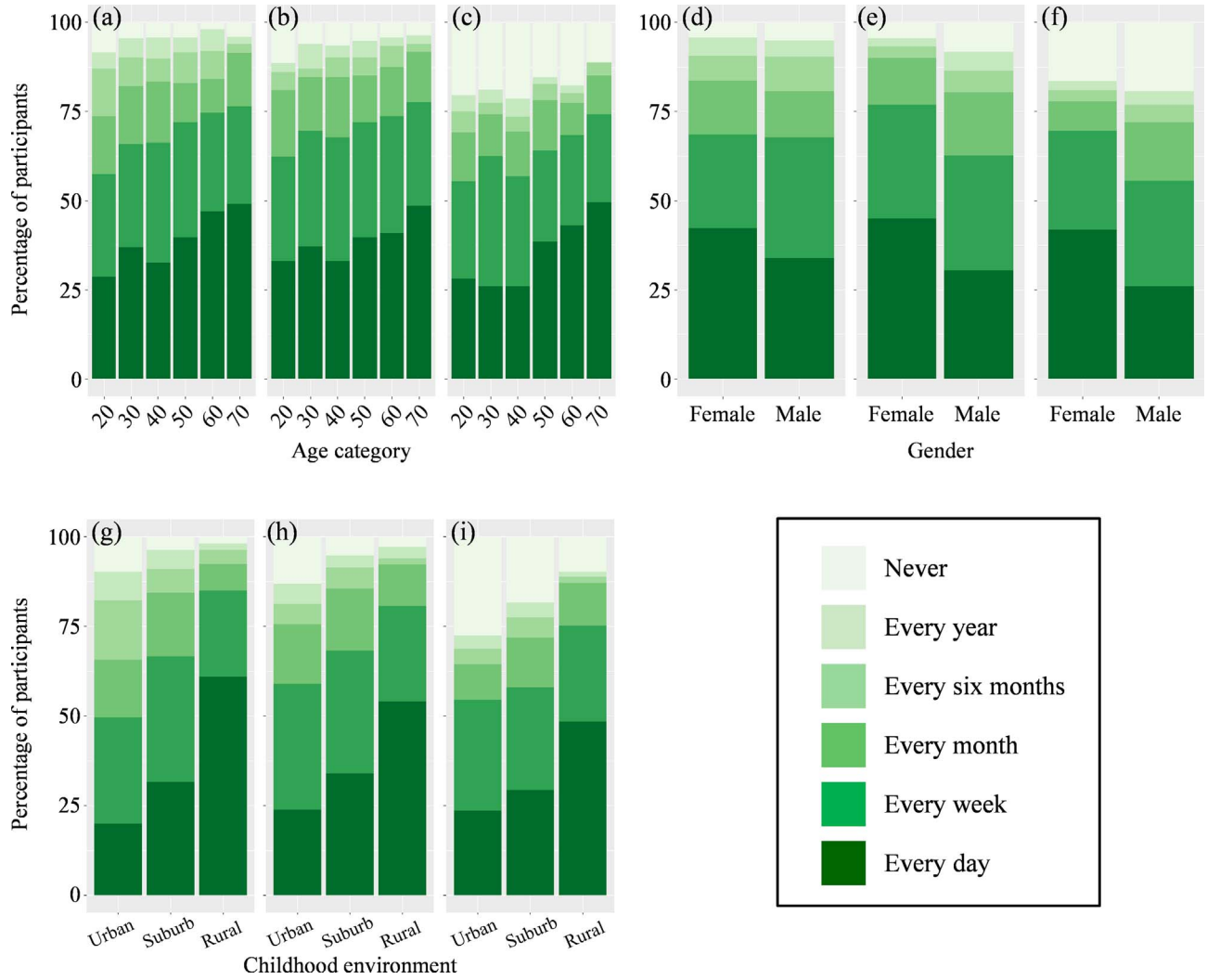

Fig. 2. Relationships between people's frequency of childhood experiences with neighborhood flowering plants and their (a, b, c) age, (d, e, f) gender, and (g, h, i) childhood environment. Frequency of (a, d, g) visiting natural environments and observing/touching neighborhood flowering plants in (b, e, h) neighborhood natural environments and (c, f, i) domestic gardens.

environment) were used as reference categories; the effect sizes of all other categories were interpreted in comparison to these reference categories. The most parsimonious model was selected using Akaike's Information Criterion (AIC). Model averaging was performed, and we retained all models where $\Delta AIC < 6$. By averaging over a subset of models, we calculated the mean estimates and 95% confidence intervals for each explanatory variable.

2.6.2. Species-level analysis

To assess the presence of age-related decline in childhood experiences with neighborhood flowering plants at a species-level, GLM analysis was performed for the data for each of the 21 species (i.e. we built 21 GLMs). Here, we developed GLMs with a log-link and a binomial error distribution. Whether the participants had directly experienced each of the 21 plant species during their childhood was used as a response variable, and explanatory variables, and interaction terms, were the same as in the above analysis. We again performed model averaging to assess the significance of each variable.

3. Results

3.1. Frequency of childhood experiences with neighborhood flowering plants

A participant's frequency of visits to neighborhood natural places was significantly associated with their gender and childhood environment: female participants (compared with male) and those who grew up in rural areas (compared with those from urban areas) reported a higher frequency of these experiences (Fig. 2; Table 2; see also Table S2). Although age did not independently affect the frequency of visits to neighborhood natural places, its effects significantly interacted with gender, meaning that the significant positive influence of age was evident only for male participants (Table 2).

A participant's frequency of observing/touching flowering plants in neighborhood natural places and domestic gardens was associated with their age, gender and childhood environment (Fig. 2c; Table 2; see also Table S2), although the effect of age on the frequency of these experiences in neighborhood natural places was marginally non-significant ($p = 0.06$; Table 2). Older and female participants and those from rural areas experienced neighborhood flowering plants more frequently (Fig. 2; Table 2). There were no significant interaction terms between the explanatory variables (Table 2).

3.2. Intensity of childhood experiences with neighborhood flowering plants

Of the 21 neighborhood flowering plant species, the median number that participants had directly experienced during childhood (i.e., intensity of childhood experiences with neighborhood flowering plants) was 3.0 (SD = 4.0) (Fig. S1). There was marked variation in the proportion of participants who had direct experiences with the different plant species (Table 1), and the most experience was with *T. repens*,

Table 2
Model-averaged parameter estimates (fixed effects) predicting participants' (a–c) frequency (ordinal logit regression models) and (d) intensity (GLMs) of childhood experiences with neighborhood flowering plants (see also Table S1 for the estimates of the threshold coefficients of ordinal logit regression models).

Variables[a]	Estimate[b]	SE[c]	P value
(a) Frequency (visiting natural environments)			
Age	0.10	0.08	0.22
Gender (male)	−0.68	0.31	0.03
Childhood environment (suburban)	0.44	0.38	0.25
Childhood environment (rural)	1.77	0.32	< 0.001
Age * Gender (male)	0.17	0.07	0.02
Age * Childhood (suburban)	0.17	0.09	0.05
Age * Childhood (rural)	0.09	0.10	0.33
(b) Frequency (experiencing of flowering plants in natural environments)			
Age	0.12	0.06	0.06
Gender (male)	−0.76	0.24	0.002
Childhood environment (suburban)	0.42	0.28	0.14
Childhood environment (rural)	1.28	0.26	< 0.001
Age * Gender (male)	0.09	0.07	0.21
Age * Childhood (suburban)	0.12	0.09	0.16
Age * Childhood (rural)	0.07	0.09	0.45
(c) Frequency (experiencing of flowering plants in domestic gardens)			
Age	0.14	0.07	< 0.05
Gender (male)	−0.59	0.16	< 0.001
Childhood environment (suburban)	0.04	0.36	0.92
Childhood environment (rural)	1.00	0.28	< 0.001
Age * Gender (male)	0.02	0.07	0.77
Age * Childhood (suburban)	0.16	0.09	0.07
Age * Childhood (rural)	0.05	0.09	0.57
(d) Intensity			
Intercept	1.18	0.07	< 0.001
Age	0.09	0.01	< 0.001
Gender (male)	−0.67	0.07	< 0.001
Childhood environment (suburban)	0.09	0.07	0.17
Childhood environment (rural)	0.32	0.06	< 0.001
Age * Gender (male)	0.07	0.02	< 0.001
Age * Childhood (suburban)	0.02	0.02	0.36
Age * Childhood (rural)	0.00	0.02	0.88

[a] In the models, gender and childhood environment were treated as categorical explanatory variables, and female (gender) and urban areas (childhood environment) were used as reference categories (see the main text).
[b] Estimate: averaged beta coefficient obtained from the weighted averages over all top models where ΔAIC < 6 (see the main text).
[c] SE: standard errors for each variable.

followed by *E. philadelphicus*, *A. sinicus*, *C. japonicum* and *C. bursa-pastoris* (Table 1). Four plant species (*E. thermalis*, *E. pinnatifida*, *P. thunbergii*, *P. senticosa*) were experienced by less than five percent of the participants (Table 1).

The reported number of plant species that participants had directly experienced during childhood was significantly associated with their age, gender and childhood environment: those who were from older generations, female, and had grown up in rural areas had experience with more neighborhood flowering plant species during childhood (Table 2). The effects of age and gender on the intensity of childhood experiences with nature significantly interacted with each other, with the effect of age being greater for male participants (Table 2).

3.3. Species-level analysis

Among the 21 plant species we investigated, age-related decline in direct experiences during childhood (i.e., significant positive effects of a participant's age on the probability of direct experiences during childhood) was observed for 9 species (*A. sinicus*; *C. japonicum*; *V. grypoceras* var. *grypoceras*; *D. superbus* var. *longicalycinus*; *S. neglecta*; *G. thunbergii*; *E. japonicum*; *A. flaccida*; *C. incisa*) (see also Table S3). Among the 11 roadside, 7 grassland/farmland and 3 woodland plant species, 2 (18.2%), 5 (71.4%) and 2 species (66.7%) had significant declines in participants' experiences during childhood, respectively (Table S3).

4. Discussion

Despite the growing attention given to extinction of experience, it remains poorly documented, particularly at large spatial scales and over the longer-term. Indeed, the majority of previous studies in this field have been performed using data from relatively small-regional and short-time scale surveys (see Soga & Gaston, 2016), making the scale and significance of this phenomenon less clear. Against this background, our study makes an important contribution to the literature by showing that extinction of experience has, at least over the last 50 years, steadily grown among the Japanese population. Indeed, our results showed a consistent downward trend in childhood experiences of neighborhood flowering plants, and this was the case even in domestic gardens, which are arguably the most easily accessible places in which people can interact with nature (Hand et al., 2017). To our knowledge, this study provides the first evidence of a nationwide decline in people's direct, spontaneous contact with neighborhood biodiversity. Given that flowering plants are one of the most popular and visible organisms for most people, this result is of particular concern as it suggests that regular, everyday interaction with local biodiversity is increasingly being lost from people's lives.

Those participants who grew up in urban areas had less childhood experience with neighborhood flowering plants than did those from rural areas. This result would most readily be explained by people's opportunity to interact with nature being more limited in urban areas (Soga et al., 2015; Zhang et al., 2014). Indeed, in Japan many large cities are very densely populated, with neighborhood public green spaces being smaller and more scarce (OECD, 2016). Given that children spend most of their free time within a limited home territory (Hand et al., 2017), the disappearance of natural places from their local environment (i.e., loss of opportunity) is likely a major factor leading to the extinction of experience.

We did not detect significant effects of the interaction between childhood environment and age on levels of childhood nature experiences, which means that the age-related decline in these experiences was evident not only in urban areas but also in rural ones, where both the quantity and quality of nature provision (i.e., opportunity) may be higher. This finding suggests that, unfortunately, the majority of children are not likely to experience neighborhood nature even if they have a plenty of opportunity (Hand et al., 2017). Indeed, it is clear that an individual's decision to interact with nature or not is not only determined by its availability (opportunity) but also by their motivation to interact with nature (orientation) (Soga & Gaston, 2016). Thus, if we are to reduce the extinction of experience it is necessary to enhance both the opportunity and orientation components in tandem.

One of the key findings of our study is that the number of neighborhood flowering plant species that participants have directly experienced during childhood was lower for younger participants compared to older ones. This could arise in two different ways. First, it could simply reflect a decline in people's frequency of childhood experiences of nature: those people who had frequent experience with nature had more chance to encounter a diversity of neighborhood plant species. In our study, frequency and intensity components were positively related to each other (Fig. S2). Second, the trend could be due to a decline in populations of neighborhood flowering plants. Indeed, our species-level analysis showed that age-related decline in childhood experiences with neighborhood flowering plants was evident particularly for grassland or farmland-dependent species (Fig. 3; Table 1), the majority of which are themselves in serious decline or facing extinction (Koyanagi & Furukawa, 2013; Suka et al., 2012). Although our data do not allow us to investigate which of the two factors has contributed more strongly to the decline in childhood intensity of experiences with neighborhood flowering plants, it suggests that levels of biological diversity that people encounter in their locale during childhood are progressively decreasing over time. From a long term viewpoint, this process can result in "shifting baseline syndrome" whereby each human

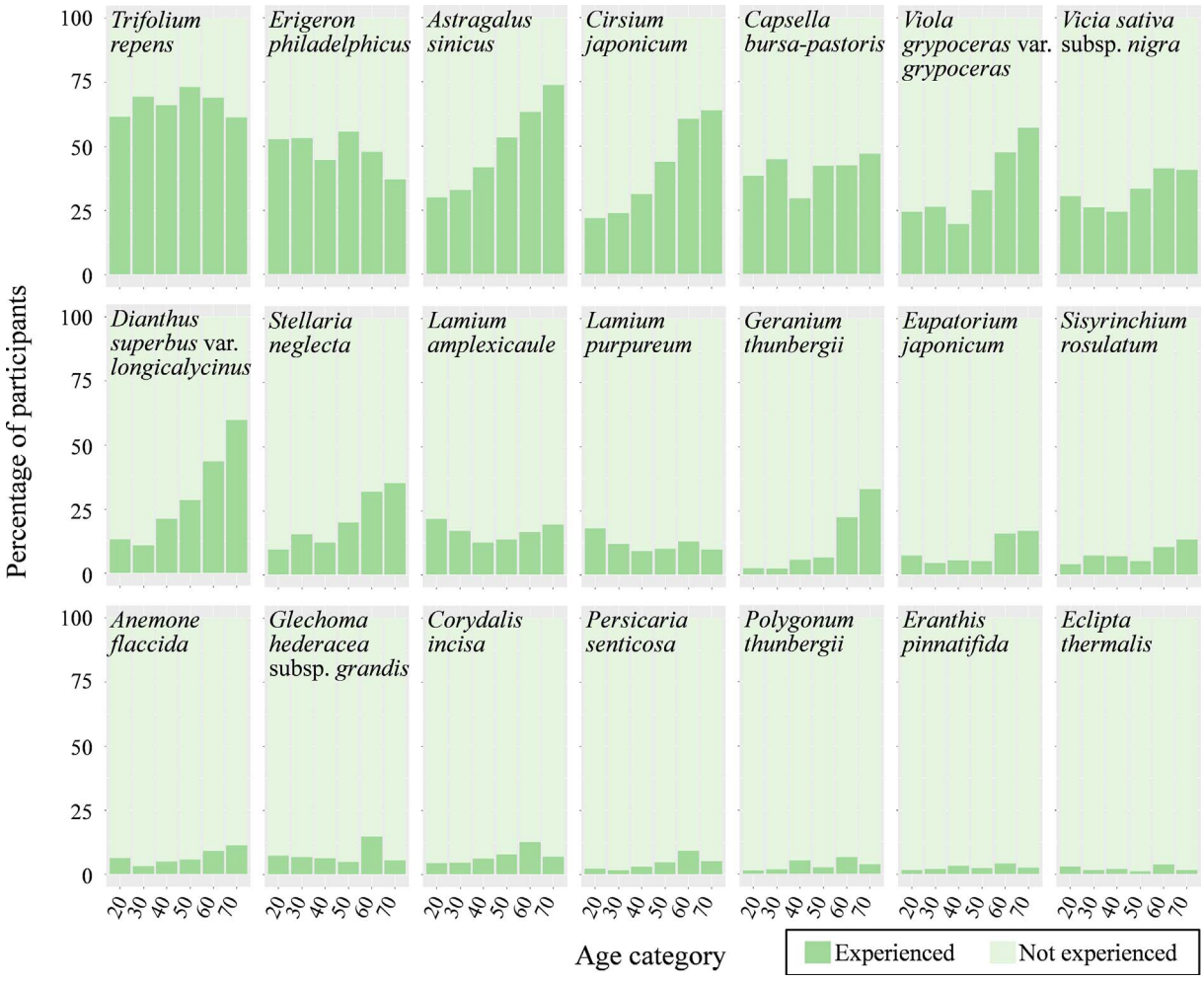

Fig. 3. Changes in the proportion of people who had direct experienced with the 21 neighborhood flowering plant species over time. Those who had experienced with flowering plants are shown in dark green (coded as "experienced"), while those who did not are in light green (coded as "not experienced"). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

generation grows up being accustomed to the way their environment looks, and thus, in a system experiencing progressive impoverishment, they do not recognize how degraded it has become over the course of previous generations (Pauly, 1995; Soga & Gaston, 2018). Given the ongoing local, regional and global collapse of biodiversity, this represents an enormous challenge for nature conservation, as it implies that our baseline standards for environmental health will continue to decline (Soga & Gaston, 2018).

Both frequency and intensity of childhood experiences with neighborhood flowering plants were higher in female compared to male participants. This result may be due to our use of wild flowers as a measure of neighborhood biodiversity. Indeed, gender differences in children's preferences toward flowers have been reported, with women being more likely to favor these organisms (Nates, Campos, & Lindemann-Matthies, 2010). Surprisingly, we found a significant effect of the interaction terms of age and gender (male) (Table 2), such that the age-related decline in people's childhood experiences of nature was evident only for male participants. Although it is difficult to explain this finding, it may partly be associated with the fact that in Japan male children are more likely to spend their time engaged with electronic media (Ministry of Internal Affairs and Communications, 2018). The increased use of screen-based media has been suggested to be a significant driver of decline in people's spontaneous experiences with nature (e.g., Clements, 2004; Pergams & Zaradic, 2006).

The findings reported here are based on a self-report online survey, an approach which has a number of advantages as well as limitations. The major advantage is the large sample that can be obtained, with a high level of stratification across the entire population at a nationwide scale. This is an important feature of our study, given that nationwide, and cross-generational, surveys have rarely been conducted in this field (Soga & Gaston, 2016). The chief limitation is the possibility of recall bias, which is a common issue arising when data have been collected from retrospective questions (Coughlin, 1990). The likelihood, and degree, of recall bias may be particularly great among elderly participants where more time has elapsed since childhood. Indeed, older participants tend to more easily forget their earlier experiences, which tends to result in an underestimate of the actual rate at which an event occurred. This would suggest that our results understate the degree of extinction of experience that has taken place. Of course, there is also the possibility that older participants might be more prone to report having had nature experiences during childhood. In general, older people tend to have higher environmental concerns and awareness (Gifford & Nilsson, 2014), raising the possibility that they answered the questionnaire more earnestly. However, we did not observe clear differences between older and younger participant groups in the time taken to complete the survey. Finally, our sample is also not entirely representative of the Japanese as a whole, and thus there is a possibility of selection bias, although it is not obvious that this could realistically result in the trends in extinction of experience that we report.

5. Conclusions

This study provides evidence that people's levels of childhood experiences of neighborhood natural environments, and their associated flowering plants, are progressively dwindling in Japan. This nationwide decline in positive human-nature interactions can potentially have several negative consequences. First, it implies a loss of health and wellbeing benefits from the natural world. Indeed, there is a considerable body of evidence showing that direct exposure to vegetated areas and associated biodiversity is linked to a wide range of positive health outcomes, including improved physical (e.g., reduced blood pressure), psychological (e.g., reduced depression), and social health (e.g., improved social cohesion) (Hartig et al., 2014; Keniger et al., 2013), and this is the case even in domestic gardens (e.g., Soga, Gaston, & Yamaura, 2017). Second, the widespread decline in children's daily experiences with nature suggests a reduction in broad-based public support for biodiversity conservation (Miller, 2005; Soga & Gaston, 2016). Childhood contact with nature is known to be a key predictor of pro-environmental attitudes and behavior in adulthood (Wells & Lekies, 2006). Given these potential implications, it is critically important to prevent the ongoing extinction of experience and its associated negative feedback loops.

There are a number of obvious ways in which this research could be extended. First, there are several additional individual characteristics that can influence the levels of childhood nature experiences, with parental values toward nature and their socio-economic status being two that warrant further investigation (e.g., Cheng & Monroe, 2012). Second, populations with different geographic, socioeconomic, and cultural backgrounds could be examined. Third, whilst we used an online questionnaire survey to assess people's levels of childhood experiences with nature, other methods such as interviews might provide complementary, and more in-depth, understanding of these relationships (e.g., Hand et al., 2017). Lastly, although the purpose of this study was to assess the magnitude of the age-related decline in childhood experiences with nature, it would be beneficial further to investigate what environmental and social factors have driven such a decline (see Fig. 1). Indeed, in Japan a number of potential driving forces can cause the extinction of experience, including rapid growth of the urban population, the emergence of digital media, the overscheduling and micromanagement of children's lives, increased parental concerns for safety if children play outdoors, and loss of neighborhood biodiversity. Undoubtedly, if we are to reduce, and ultimately reverse, the ongoing loss of human-nature interactions, we need fully to understand the underlying mechanisms involved.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2018.02.009.

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