From beauty to belief: The aesthetic and diversity values of plants and pets in shaping biodiversity loss belief among urban residents

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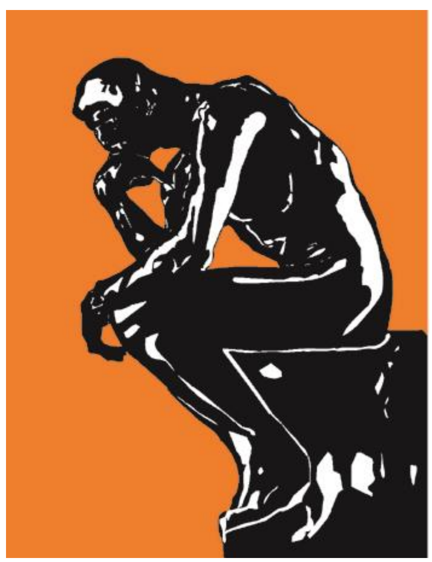

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Abstract

Aesthetics is a crucial ecosystem service provided by biodiversity, which is believed to help improve humans' quality of life and is linked to environmental consciousness and pro-environmental behaviors. However, how aesthetic experience induced by plants/animals influences the belief in the occurrence and significance of biodiversity loss among urban residents remains understudied. Thus, the current study aimed to examine how the diversity of pets and in-house plants affect urban residents' belief in biodiversity loss in different scenarios of aesthetic experiences (positive and negative aesthetic experiences at home due to plants/animals). Using the Bayesian Mindsponge Framework (BMF) analytics on a dataset of 535 Vietnamese urban residents, we found that the people's aesthetic feeling about their house induced by plants/animals positively affects their belief in the occurrence and significance of biodiversity loss. The diversity of plants and pets also positively influences the level of biodiversity loss belief, but the effect is conditional on the aesthetic experience of the urban residents. Specifically, the positive impact of species diversity on the belief only exists when urban residents feel that their houses' aesthetics are negatively affected by plants/animals. Moreover, the effect of pet diversity on biodiversity loss belief is less significant and reliable than that of plant diversity. These findings suggest that raising the houses' aesthetics through in-house planting or pet ownership can potentially enhance biodiversity loss belief and subsequently build an eco-surplus culture among urban residents.

Keywords: aesthetic appreciation; biodiversity conservation; denialism; Mindsponge Theory; BMF analytics

> "His style and performance are immaculate. His colorful feather is beautiful to the littlest details, so much so that he is very popular among the lady kingfishers who would fly in from very far away to flirt with him."
>
> In "Flower Kingfisher"; *The Kingfisher Story Collection* Vuong (2022)

1. Introduction

More than half of the world's population now lives in cities, making urbanized areas the most rapidly expanding habitat type (Grimm et al., 2008). The expansion of cities causes habitat loss, reductions in habitat quality, and fragmentation (McKinney, 2008). These ramifications are the main drivers of biodiversity loss in multiple taxa, including birds, amphibians, arthropods, and fungi (Bainard et al., 2011; Hamer & Parris, 2011; Herrmann et al., 2012; McIntyre et al., 2001; Shochat et al., 2010). To alleviate the problem, many researchers have endorsed the idea of improving and conserving the biodiversity level within cities. Besides tackling the biodiversity-extinction crisis, urban biodiversity conservation can provide ecosystem services that contribute to improving human health and well-being and enhancing connectedness to nature (Cox et al., 2017; De Bell et al., 2018; Shanahan et al., 2015; Soanes et al., 2023). Among various biodiversity's ecosystem services, aesthetic value is one of the notable benefits that humans can directly perceive (Tribot et al., 2018). It is also believed to contribute to quality of life, health, or vitality by delivering inspiration, harmony, and peace (Millennium Ecosystem Assessment, 2005).

According to Chatterjee and Vartanian (2016), aesthetics encompasses a wide range of sensory experiences, including visual, auditory, and even emotional elements, so it is a key determinant in how individuals connect with and experience the surrounding spaces in urban contexts (Gobster et al., 2007). The aesthetics of urban spaces can evoke emotions, establish the atmosphere for social interactions, and even influence an individual's sense of belonging (Wang & Yu, 2018). Beautifully designed public spaces, vibrant street art, well-maintained green areas, and thoughtfully planned infrastructure can create a sense of harmony and engagement for residents and visitors alike (Mansor et al., 2012). Within urban settings, the coexistence of diverse plant species and animals, often found near water bodies like lakes or rivers and in urban green spaces, elicits a sense of harmony and tranquility (Szlavecz et al., 2011). This phenomenon fosters people's profound connection with the surrounding natural world (Lepczyk et al., 2017; Nisbet et al., 2020), thus generating an environment that facilitates emotional bonds and nurtures a profound sense of belonging (Berger et al., 2022).

In urban settings, plants and pets are two common sources of natural information. Diverse plant environments are crucial for the well-being of the environment and human communities (Sandifer et al., 2015). According to Janeczko et al. (2020), urban environments with lush greenery can positively affect people's physical and psychological well-being. These environments contribute to mitigating allergies, reducing mortality rates, and promoting general wellness (Aerts et al., 2018). Urban vegetation has the capacity to provide refreshment and relaxation, similar to the benefits observed in wooded settings. In addition, exposure to natural settings helps reduce stress and cognitive strain and improves learning (Vella-Brodrick & Gilowska, 2022).

As for pets, traditional options like dogs and cats remain popular today. However, other species, like birds and arthropods, are increasingly acknowledged for their capacity to acclimate to urban environments, thereby establishing a unique niche for themselves (Faeth et al., 2011). Global urbanization prompts a reconsideration of their importance to humans. In densely populated urban areas, where loneliness and alienation are prevalent, pets as companions gain increased importance (Wong et al., 2019). Pets do more than be a companion (Fudge, 2014). They can offer emotional support and assist with mental health. For instance, interactions with dogs can induce positive emotions, including heightened levels of the "happy hormone" endorphins (Hasin et al., 2018).

Beliefs are key factors that shape individuals' cognitive processes and behaviors in relation to the environment (Ajzen, 1985, 1991; De Leeuw et al., 2015; Johnson et al., 2021; Lou et al., 2020; Nguyen, Nguyen, et al., 2023; O'Connor et al., 1999). Belief in the existence of biodiversity loss can be deemed as a safeguard against extinction denialism and a facilitator of pro-conservation thinking and behaviors (Lees et al., 2020; Menzel & Bögeholz, 2010; Nguyen, Nguyen, et al., 2023). Despite its importance, few studies have been conducted to examine the factors predicting the belief in biodiversity loss. Although aesthetic experiences of nature and wildlife species are positively linked to environmental ethics, pro-environmental intentions and behaviors (de Pinho et al., 2014; Pereira & Forster, 2015; Tribot et al., 2018; Wang & Yu, 2018), how aesthetic experiences of nature affect the belief in biodiversity loss seems to be missing. As a result, a significant gap persists in understanding how the diversity of pets, in-house plants, and the aesthetics induced by plants/animals interactively shape the beliefs of urban residents concerning biodiversity loss.

Given these gaps in the literature, the current study aimed to explore how the diversity of pets and in-house plants affect Vietnamese urban residents' belief in biodiversity loss in different scenarios of aesthetic experiences (positive and negative aesthetic experiences at home due to plants/animals). The Mindsponge Theory was employed to aid reasoning the psychological process behind the studied associations. The Bayesian Mindsponge Framework (BMF) analytics was utilized on a dataset of 535 Vietnamese urban residents across 35 cities in Vietnam to validate the reasoning.

2. Methodology

2.1. Theoretical foundation

Mindsponge Theory, a theory of the human mind's information processing, was used as the theoretical foundation of this study to examine how access to pet and plant diversity affects urban humans' belief in biodiversity loss in two aesthetic conditions (Vuong, 2023). The theory was developed from the mindsponge mechanism, a socio-psychological framework of the value absorption and ejection of the human mind, and induced by the most recent findings from the brain and life sciences (Vuong & Napier, 2015). The theory is grounded on the information-processing approach to studying the human mind. This approach posits that information serves as the fundamental basis for constructing physical reality, hence facilitating the exploration of intricate phenomena that need a multidisciplinary understanding (Davies & Gregersen, 2014). Numerous studies have employed the theory as a foundational framework to explore socio-psychological phenomena, encompassing the domains of environmental and conservation psychology (Asamoah et al., 2023; Cheng et al., 2023; Jiang et al., 2022; Khuc et al., 2023; Kumar et al., 2022; Nguyen & Jones, 2022a, 2022b; Nguyen & Vuong, 2021; Santirocchi et al., 2023; Tanemura et al., 2022; Vuong, Le, Jin, et al., 2023; Vuong, Le, et al., 2022; Vuong, Le, La, et al., 2023).

The human mind and environment are considered the two main spectrums of the study. The theory views the human mind as an information collection-cum-processor, which helps explain the way people perceive, think, believe, behave, and establish social constructs (Vuong, 2023). Meanwhile, the environment is conceptually a broader information-processing system (e.g., the Earth system, the social system, etc.) encompassing the human mind. The mind processor's inputs are information that is absorbed from the surrounding environment or stored in the memory, while its outputs are things that drive human thinking processes and behaviors, such as value systems, perceptions, thoughts (including creative ideas), feelings, etc. The outputs and perceived feedback from the environment will become inputs for subsequent information processes. The mind is constituted by the mindset, buffer zone, and multi-filtering system. The theory defines mindset as a collection of highly trusted information (core values or beliefs) within the human mind. The buffer zone is a conceptual area in which information is temporarily stored before undergoing evaluation by the multi-filtering system (Vuong, Nguyen, et al., 2022).

Due to the interconnectedness of biological systems, the mindset is not a steady information collection. It is continually updated due to the dynamic nature of cellular information exchange and the adaptability of neurological systems. The updating processes in human minds use a process known as "live-wiring" rather than the more prevalent "hard-wiring" observed in simpler systems, which rely more heavily on predetermined genetic information (Eagleman, 2015). This phenomenon can be attributed to neuroplasticity (Galván, 2010; Mateos-Aparicio & Rodríguez-Moreno, 2019). As a result, the mindset's content is likely influenced by the information availability and accessibility in the surrounding environment as well as the multi-filtering process.

For absorbed information from the environment to become highly-trusted information (core values or beliefs), it needs to pass through the multi-filtering system of the mind. When new information enters the mind, it is treated in two different ways: Information integration and differentiation. If the newly absorbed information is aligned with the existing highly trusted information in the mindset, it will be quickly synthesized and integrated into the mindset. If the newly absorbed information exhibits substantial discrepancies with the existing core values, it will undergo evaluation through a differentiation process in which the cost-benefit assessment will determine whether the emerging information is rejected or accepted (Vuong, Nguyen, et al., 2022). In some cases, when the perceived benefits of accepting new information greatly surpass those of keeping existing core values, the new information will replace the core values. Generally, if new information is perceived as potentially beneficial, it is likely to be assimilated into one's mindset and subsequently affect thinking processes, filtering systems, and behaviors. Conversely, if the information is perceived as costly, it will likely be dismissed. When perceived costs and benefits are ambiguous, the information will be temporarily stored in a buffer zone until sufficient data is available for evaluation (Vuong, Nguyen, et al., 2022).

Based on the cognitive processes presented above, it is reasonable to assume that Vietnamese urban people's belief in biodiversity loss depends on the availability and accessibility of biodiversity-related information and the multi-filtering process. In urban settings, particularly in Vietnam, the availability of green spaces, such as public parks, is diminishing as a result of urban development, hence greatly limiting the opportunities for urban dwellers to obtain biodiversity-related information in public settings (Nguyen, 2017; VietNamNet Bridge, 2018). There exist two major pathways via which urban residents in Vietnam might obtain information pertaining to biodiversity. The first way involves the utilization of information transmitters, such as the Internet, books, films, and other comparable media. Another way entails pet ownership and engaging in different kinds of planting, such as home gardening, among other possibilities. The first approach cannot provide urban residents with firsthand experience of the benefits of biodiversity and the negative consequences of biodiversity loss. In contrast, the latter approach enables persons to interact directly with animals or plants, allowing them to perceive the services these species offer. When urban residents can perceive the benefits provided by biodiversity, their mindsets might favor biodiversity-related information during the information-seeking, -selecting, and -filtering processes, making them more likely to believe in biodiversity loss. Thus, we assume that urban residents who own more types of pets and in-house plants are more likely to believe in biodiversity loss.

Besides the access to the diversity of pets and in-house plants, we also expected the aesthetic experience of the house induced by pets/plants to contribute to the mind's filtering process. Aesthetics has several different and complementary definitions that are contingent on the specific discipline within which it is delineated, such as art, philosophy, social science, and cultural history (Tribot et al., 2018). In the current study, we examined the urban residents' aesthetic experience of their houses due to plants/animals, so the definition of landscape aesthetics is preferable. Landscape aesthetics is defined as aesthetic benefits people receive through their senses and interactions with the landscapes (Swaffield & McWilliam, 2013). The aesthetics can be divided into two complementary approaches (Tribot et al., 2018): 1) the transmitter approach, which is associated with the inherent value of a landscape, as evaluated by its biophysical attributes that stimulate an aesthetic response (Fry et al., 2009), and 2) the receiver approach, which describes the landscape through the lens of human perception (Chatterjee, 2014; Müderrisoğlu & Gültekin, 2015).

From the mindsponge information-processing perspective, people's aesthetic experience can be redefined as a positive perception of aesthetics – an outcome of the information process using information absorbed through the observation of the surrounding environment and highly trusted information stored within the mindset. The absorbed information through the sensory system reflects the biophysical characteristics of the environment. However, when the information enters the mind, it will become a subjective value that is more or less influenced by the previously existing information in the mind, especially the core values

(Vuong et al., 2021). For that reason, the aesthetic experience of a person is dependent on not only the biophysical attributes of the surrounding environment but also the information priorly existing within the mind.

According to the Mindsponge Theory, the outcome of an information process will be used as input for the subsequent information process (Vuong, 2023). Therefore, the aesthetic experience with the house induced by pets/plants will also contribute to assessing information related to biodiversity. If the experience is positive, biodiversity-related information will be perceived as more beneficial and more likely to be integrated into the mindset. On the contrary, if the experience is negative, the information will be perceived as costly and more likely to be ejected from the mind. Based on this reasoning, we assumed that urban residents' aesthetic experience of their house due to plants/animals would affect (or moderate) the relationship between access to the diversity of plants and pets and belief in biodiversity loss. To validate the assumptions in this subsection, we select the variables and construct the model in the next subsection.

2.2. Model construction

2.2.1. Variable selection and rationale

This study used secondary data from a dataset of 535 urban residents from 35 cities across Vietnam. The dataset is about urban residents' multifaceted perceptions toward biodiversity–human interactions in Vietnam, which is constructed with six major categories, namely: 1) wildlife product consumption, 2) general biodiversity perceptions, 3) biodiversity at home and neighborhood, 4) public park visitation and motivations, 5) national park visitation and motivations, and 6) socio-demographic profiles (Nguyen, 2021).

Before the survey was distributed, it was designed based on the interview results of urban residents in the two largest cities in Vietnam. A total of 38 individuals residing in Hanoi and Ho Chi Minh City were engaged in comprehensive interview sessions conducted between November 15 and December 26, 2020. The interviewees' age, gender, occupation, and prior experiences with nature were considered during the interviewee selection process to diversify their viewpoints. The interview process was completed when it reached "theoretical saturation," when no new information or perspectives emerged from the data collected (Creswell & Poth, 2018).

After the questionnaire design was finalized, the survey was collected using the snowball sampling technique through a Web-based platform, Google Forms. Prior to undertaking the survey, participants were instructed to read the survey's contents and objectives and provide their agreement to the consent form. Five hundred eighty-one responses were acquired between June 18 and August 8, 2021. However, only 535 responses were eligible for analysis after the four-step quality check. All low-quality replies were eliminated, including those from non-urban inhabitants, those under the age of 18, those with repeated emails, and those with suspected low-quality signals. Finally, all the responses were encoded and saved under a comma-separated value format.

The dataset was peer-reviewed by two referees before it was published in *Data Intelligence*:

- https://direct.mit.edu/dint/article/3/4/578/107428/Multifaceted-Interactions-between-Urban-Humans-and

For the research objective of the current study, four variables were employed for the statistical analysis. To measure the urban resident's belief in biodiversity loss, we employed *BioLossBelief* variable, which reflects how the respondent viewed the biodiversity loss phenomenon. The respondents' self-reported numbers of pet and plant types at home were utilized to estimate the respondent's access to biodiversity-related information. Those self-reported numbers are represented by *AnimalDiversity* and *PlantDiversity* variables, respectively. Finally, the aesthetic experience of the respondent was represented by the variable *HomeAesthetic*, which was measured by the question: "How much does the presence of plants/pets affect the aesthetic of your house?" If the respondent answered 'very negative effect' or ' negative effect,' they would be encoded as 'negative effect.' In contrast, if the respondent answered 'very positive effect' or 'positive effect,' they would be encoded as 'positive effect.'

Table 1: Variable Description

Variable	Variable in the original dataset	Description	Data type	Value
BioLossBelief	*B2*	Belief in biodiversity loss	Numerical	1 = Biodiversity loss is not real 2 = Biodiversity loss is real but only a small problem 3 = Biodiversity loss is real and a major environmental problem

AnimalDiversity	*C2_3*	The number of types of pets that the respondent owns	Numerical	0 = No pet 1 = One type of pet 2 = Two types of pets 3 = More than two types of pets
PlantDiversity	*C1_3*	The number of types of plants planted in the respondent's house	Numerical	0 = No plant 1 = One type of plant 2 = Two types of plants 3 = Three types of plants 4 = Four types of plants 5 = Five types of plants 6 = More than five types of plants
HomeAesthetic	*C3_4*	Whether the respondent feels the house aesthetic due to plant/animal	Binary	1 = Positive effect 0 = Negative effect

2.2.2. Statistical model

To validate the assumptions presented in Subsection 2.1, we constructed model 1:

$$BioLossBelief \sim normal(\mu, \sigma) \tag{1.1}$$

$$\mu_i = \beta_0 + \beta_1 * AnimalDiversity_i + \beta_2 * PlantDiversity_i + \beta_3 * HomeAesthetic_i + \beta_4 * AnimalDiversity_i * HomeAesthetic_i + \beta_5 * PlantDiversity_i * HomeAesthetic_i \tag{1.2}$$

$$\beta \sim normal(M, S) \quad (1.3)$$

The probability around μ is determined by the form of the normal distribution, whose width is specified by the standard deviation σ. μ_i indicates the probability that urban resident i' has the belief in the occurrence and significance of biodiversity loss; $AnimalDiversity_i$ indicates the number of pet types that the urban resident i owned; $PlantDiversity_i$ indicates the number of plant types that the urban resident i owned; $HomeAesthetic_i$ indicates the whether the urban resident i felt their home aesthetic due to plant/animal; β_4 and β_5 indicate the coefficients of the non-additive effects of $AnimalDiversity_i$, $PlantDiversity_i$, and $HomeAesthetic_i$ on $BioLossBelief$. If the coefficients β_4's and β_5's distributions are significant, and the associations between the species diversity and biodiversity loss belief are considered conditional on aesthetic feeling. Model 1 has seven parameters: the coefficients, β_1 – β_5, the intercept, β_0, and the standard deviation of the "noise", σ. The coefficients are distributed as a normal distribution around the mean denoted M and with the standard deviation denoted S. The logical network for Model 1 is presented in Figure 1.

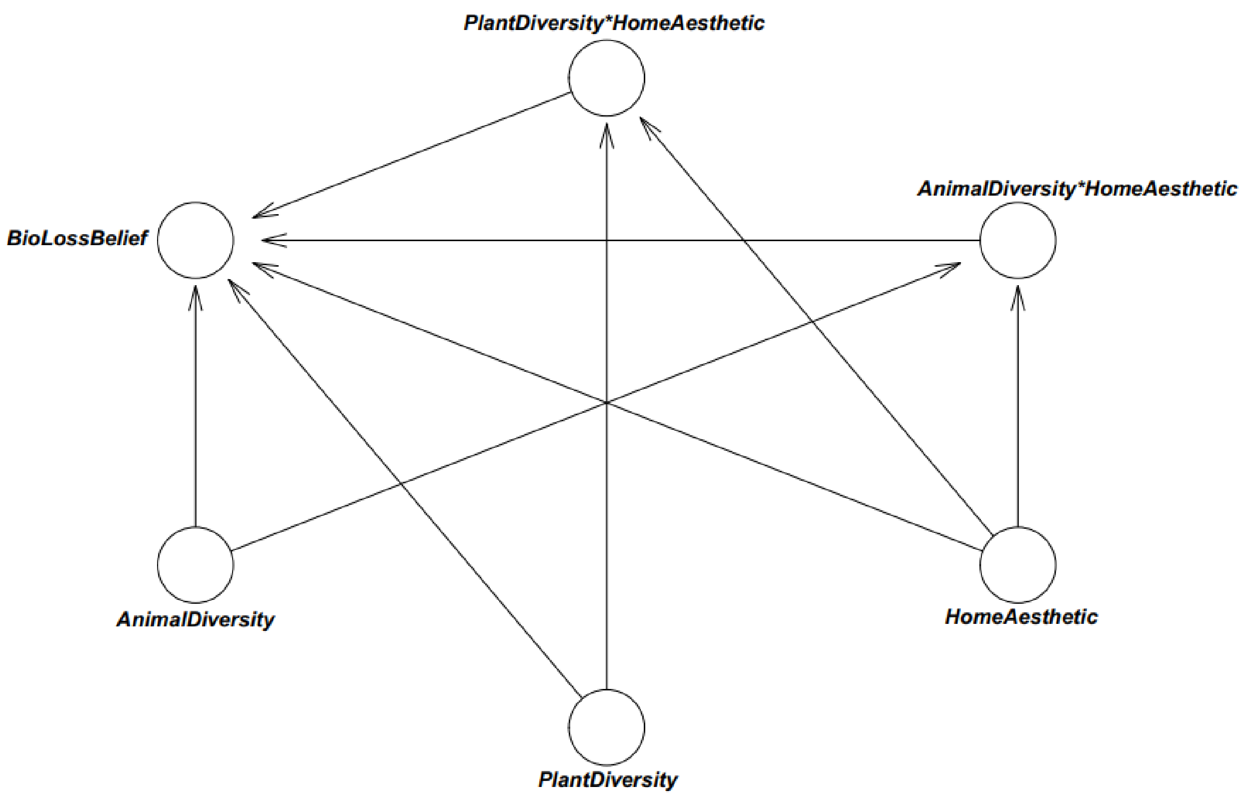

Figure 1. Model 1's logical network

2.3. Analysis and validation

Bayesian Mindsponge Framework (BMF) analytics was employed in the current study for several reasons (Nguyen et al., 2022; Vuong, Nguyen, et al., 2022). First, the method integrates the logical reasoning capabilities of Mindsponge Theory with the inferential advantages associated with Bayesian analysis, as these two approaches exhibit a high degree of compatibility (Nguyen et al., 2022). Second, Bayesian inference is a statistical approach that treats all the properties (including the known and unknown ones) probabilistically (Csilléry et al., 2010; Gill, 2014), enabling reliable prediction of parsimonious models. Nevertheless, utilizing the Markov chain Monte Carlo (MCMC) technique still allows Bayesian analysis to deal effectively with various intricate models, such as multilevel and nonlinear regression frameworks (Dunson, 2001). Third, Bayesian inference has various advantages in comparison to the frequentist approach. One notable advantage is the ability to utilize credible intervals for result interpretation instead of relying solely on the dichotomous decision based on *p*-values (Halsey et al., 2015; Wagenmakers et al., 2018).

In Bayesian analysis, selecting the appropriate prior is required during the model construction process. Due to the exploratory nature of this study, uninformative priors or a flat prior distribution were used to provide as little prior information as possible for model estimation (Diaconis & Ylvisaker, 1985). After the model was fitted, we employed the Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics to check the models' goodness-of-fit (Vehtari & Gabry, 2019; Vehtari et al., 2017). LOO is computed as follows:

$$LOO = -2LPPD_{loo} = -2\sum_{i=1}^{n} \log \int p(y_i|\theta)p_{post(-i)}(\theta)d\theta$$

$p_{post(-i)}(\theta)$ is the posterior distribution based on the data minus data point i. The k-Pareto values are used in the PSIS method for computing leave-one-out cross-validation, which helps identify observations with a high degree of influence on the PSIS estimate. Observations with k-Pareto values greater than 0.7 are often considered influential and may be problematic for accurately estimating leave-one-out cross-validation. Commonly, a model is considered fit when the k values are below 0.5.

If the model had a good fit with the data, we would proceed with the convergence diagnoses and result interpretation. In the current study, we validated the convergence of Markov chains using statistical values and visual illustrations. Statistically, the effective sample size (*n_eff*) and the Gelman–Rubin shrink factor (*Rhat*) can be used to assess the convergence. The *n_eff* value represents the number of iterative samples that are not autocorrelated during stochastic simulation, while the *Rhat* value is referred to as the potential scale reduction factor or the Gelman–Rubin shrink factor (Brooks & Gelman, 1998). If *n_eff* is larger than 1000, it is generally considered that the Markov chains are convergent, and the effective samples are sufficient for reliable inference (McElreath, 2018). As for the *Rhat* value, if the value exceeds 1.1, the model does not converge. Typically, the model is considered convergent if $Rhat = 1$. Visually, the Markov chains' convergence was also validated using trace plots, Gelman–Rubin–Brooks plots, and autocorrelation plots.

The Bayesian analysis was performed on R using the **bayesvl** open-access package, which provides good visualization capabilities (La & Vuong, 2019). Considering the issues of data transparency and the cost of reproduction, all data and code snippets of this study were deposited onto an Open Science Framework (OSF) server (Vuong, 2018): https://osf.io/w8dvg/.

3. Results

PSIS-LOO diagnostics shows that all *k* values are below the threshold of 0.5, indicating that the constructed model fits well with the dataset (see Figure 2). Thus, the estimated results can be interpreted.

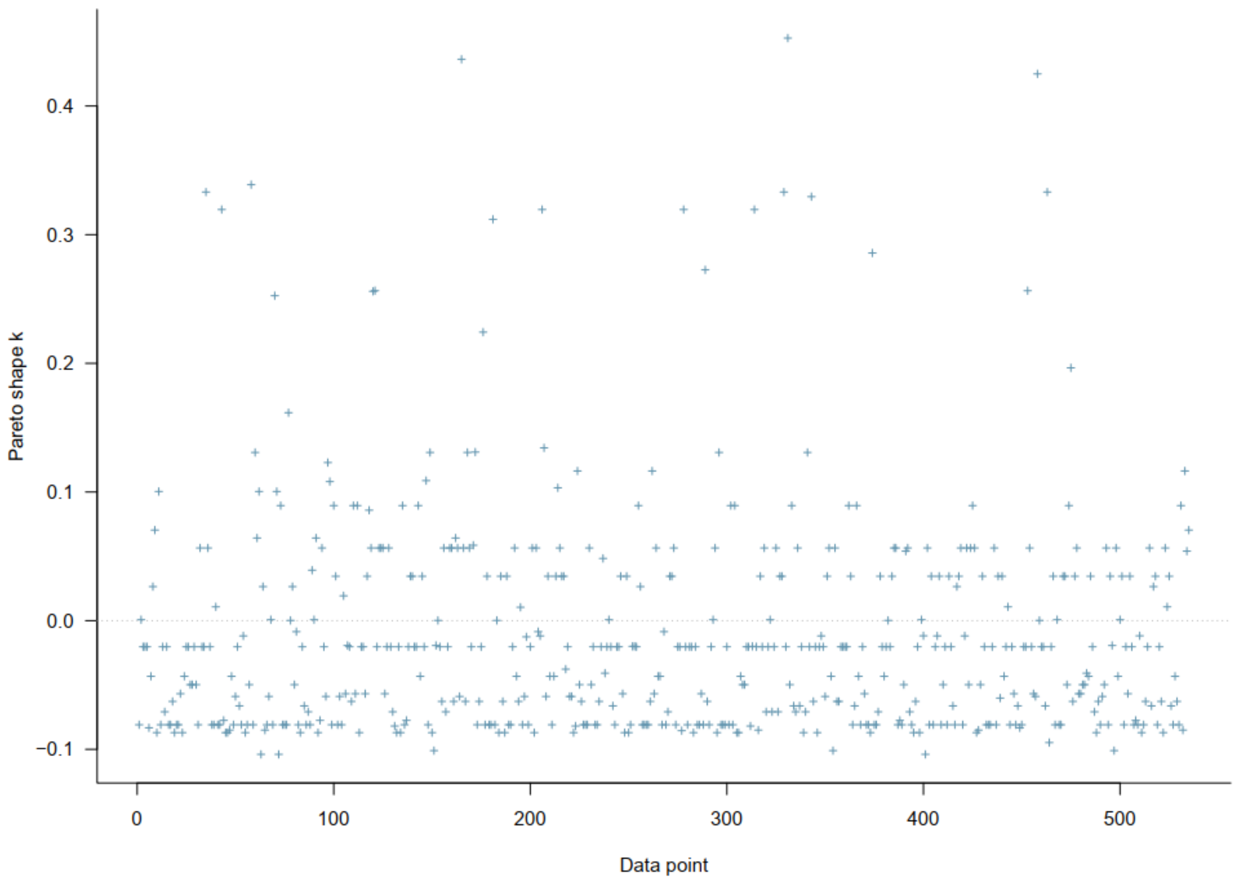

Figure 2. PSIS-LOO diagnostic plot

Table 2 shows the estimated posteriors of the analytical model's parameters and convergence diagnostic values (i.e., *n_eff* and *Rhat*). All the n_eff values are above 1000, and all Rhat values equal 1, so the model's Markov chains can be deemed convergent.

Table 2. Estimated posteriors

Parameters	Mean	SD	n_eff	Rhat

Constant	2.28	0.20	3921	1
HomeAesthetic	0.57	0.21	3914	1
AnimalDiversity	0.07	0.09	5082	1
*AnimalDiversity*HomeAesthetic*	-0.07	0.10	5043	1
PlantDiversity	0.10	0.05	3716	1
*PlantDiversity*HomeAesthetic*	-0.09	0.05	3715	1

The convergence of the Markov chains is also validated by the trace plots (see Figure 3), Gelman-Rubin-Brooks plots (see Figure 4), and autocorrelation plots (see Figure 5). In the trace plots, all the chains fluctuate around central equilibriums after the warm-up period (2000th iteration). This is a good signal of convergence.

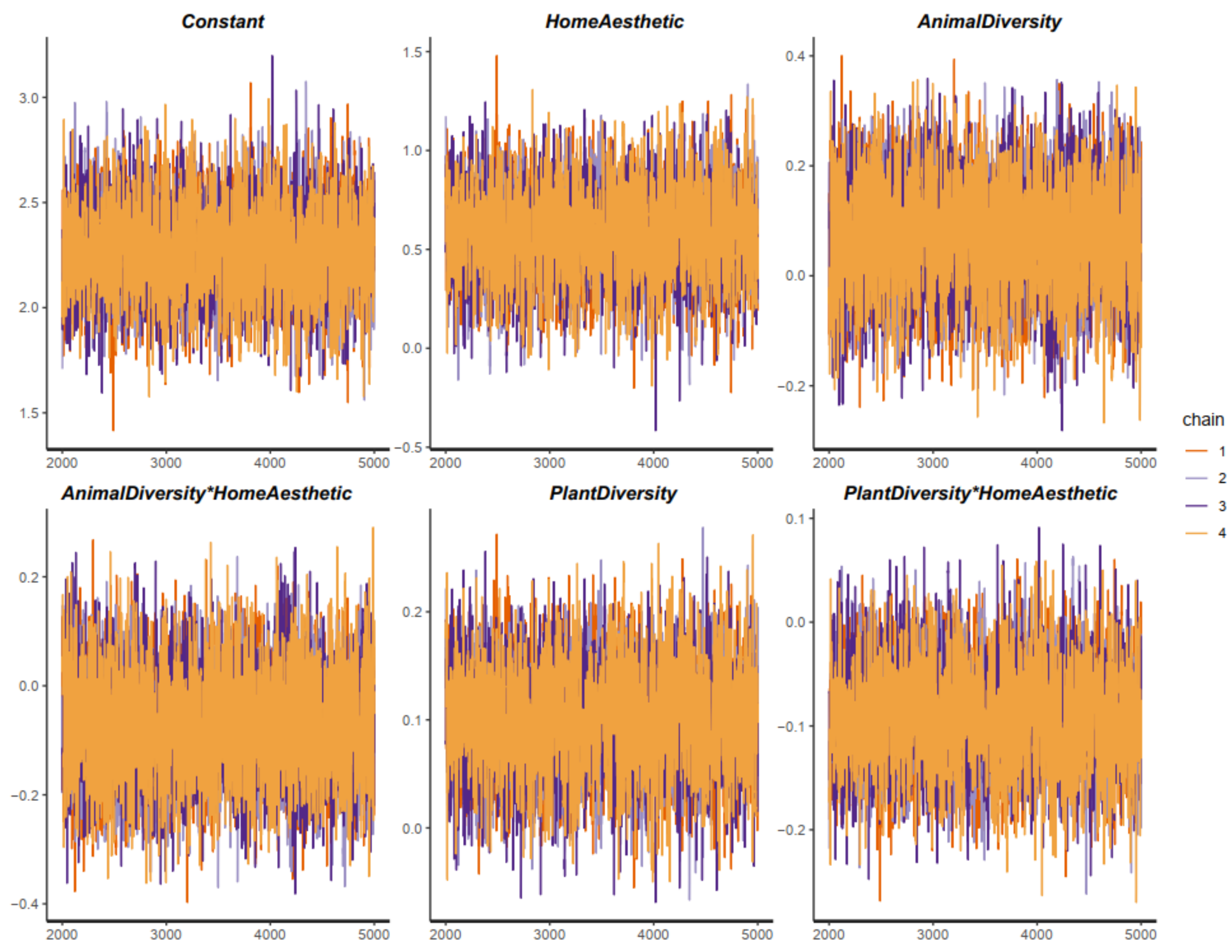

Figure 3. Trace plots for the model

The purpose of the Gelman-Rubin-Brooks plot is to assess whether the *Rhat* value (or shrink factor) drops to 1 prior to the completion of the warm-up period. The simulated samples may be considered convergent if the shrink factor drops to 1 prior to the 2000th iteration. The autocorrelation plot visually represents the level of correlation between Markov Chain Monte Carlo (MCMC) samples that are separated by different lags. When the autocorrelation levels of iterative samples reach 0 after some limited lags, the samples are regarded as independent, indicating the convergence of the Markov chains. Figure 4 shows that the shrink factor declines to 1 before the warm-up period completes, while Figure 5 demonstrates the rapid drop of autocorrelation levels after finite lags. These two signals confirm the convergence of Markov chains.

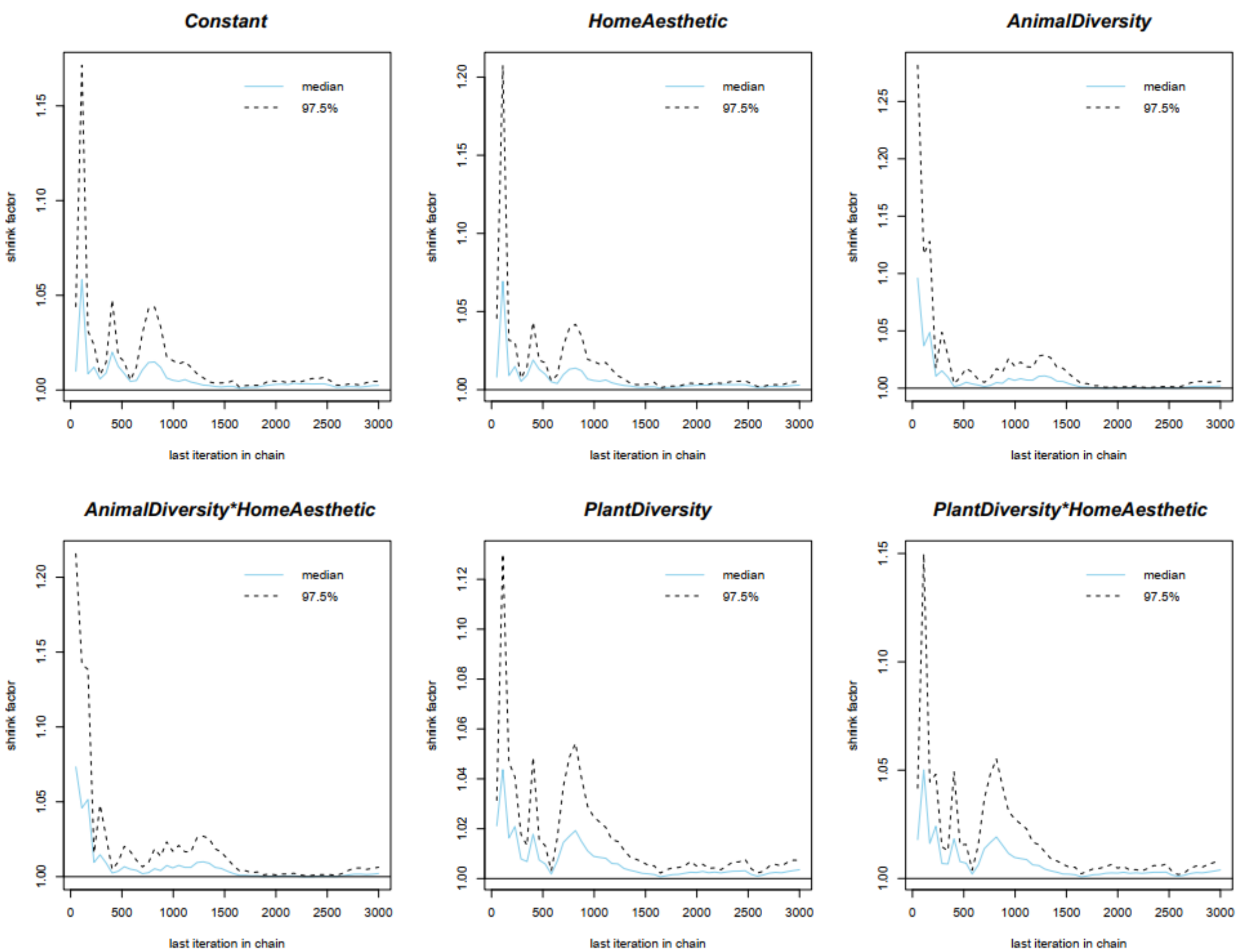

Figure 4. Gelman-Rubin-Brooks plots

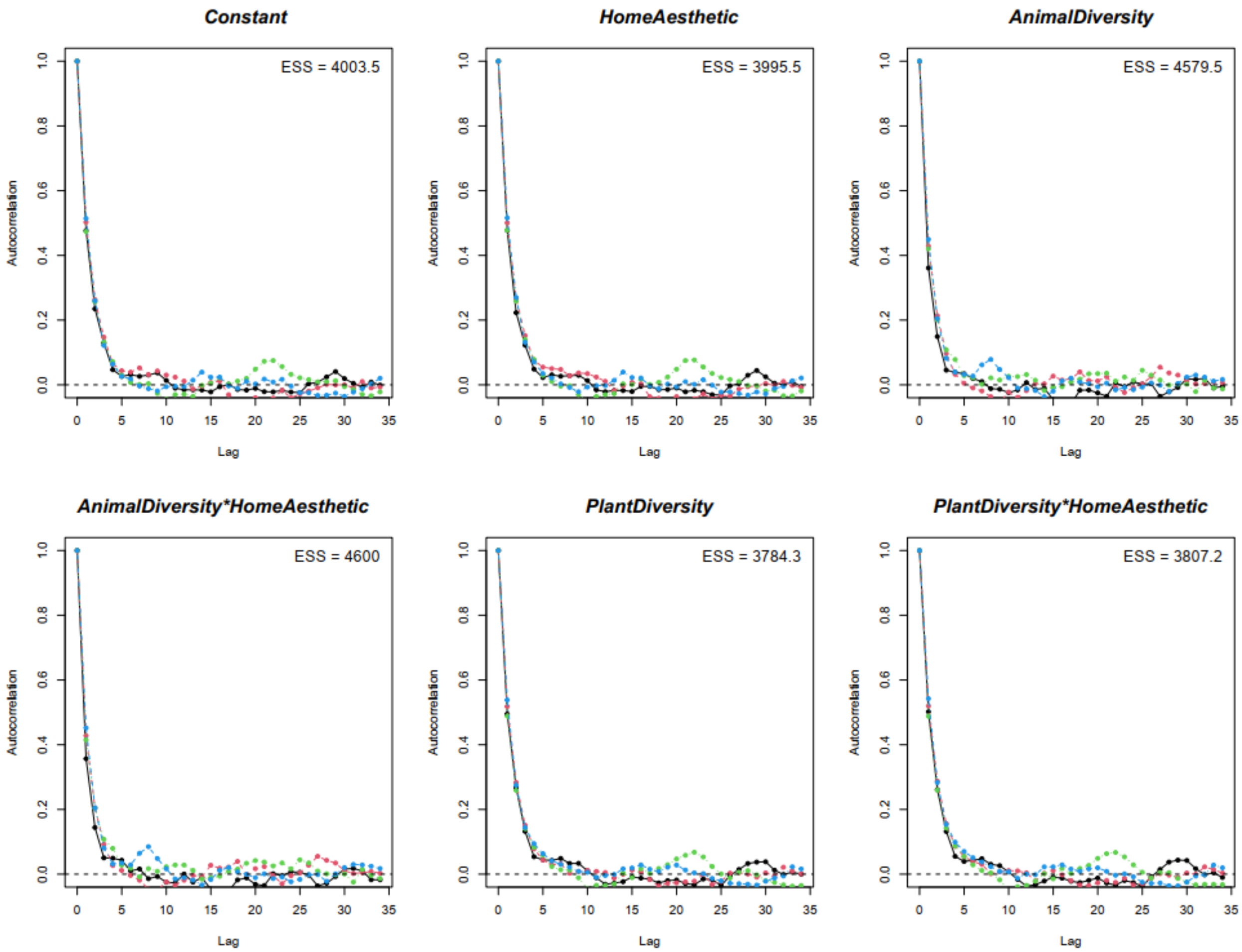

Figure 5. Autocorrelation plots

Table 2 presents the estimated posterior distributions of the constructed model, and Figure 6 illustrates them. Since the constructed model is complex, it is necessary to visualize the findings before interpreting them. However, before the result interpretation, the findings' reliability and robustness need to be evaluated.

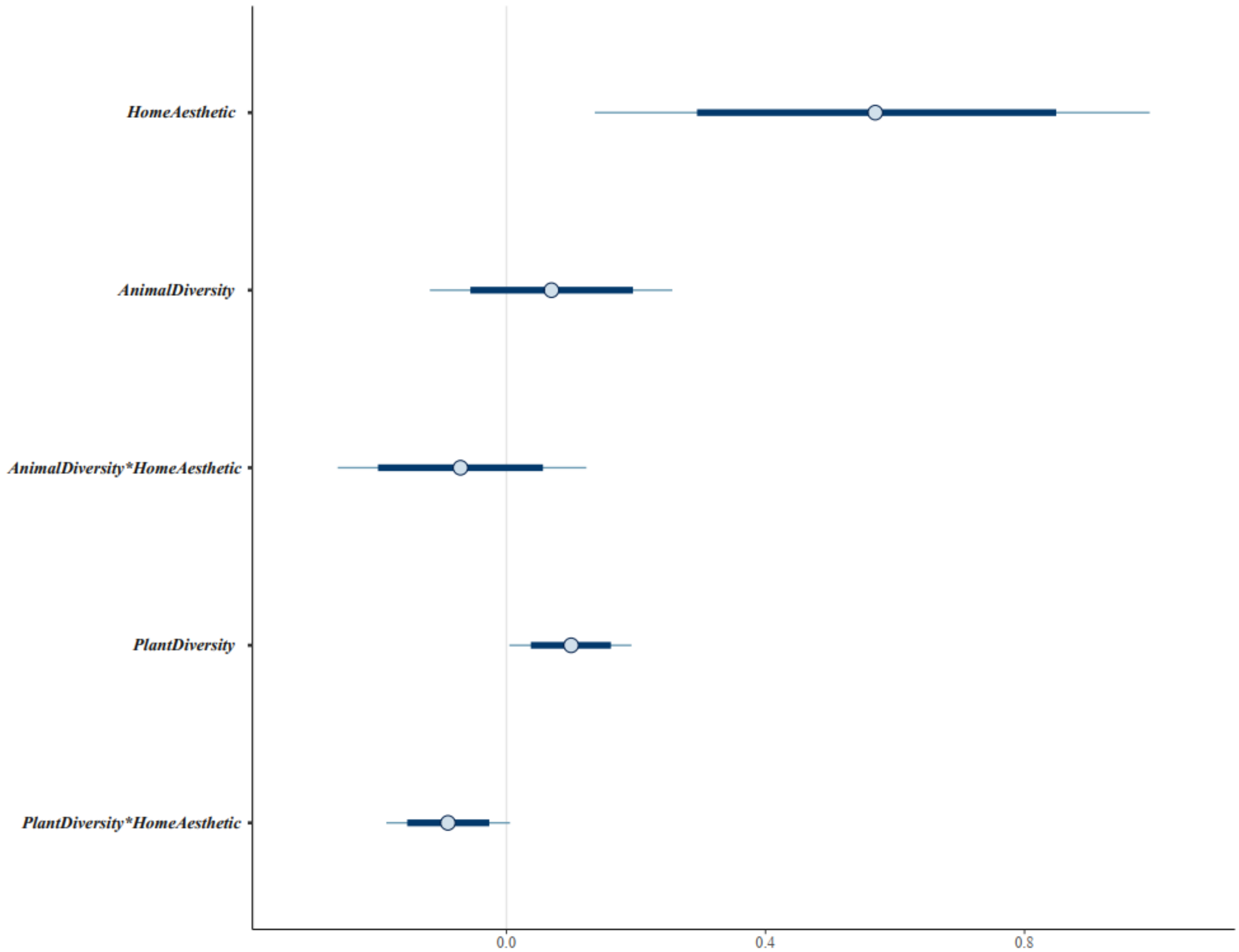

Figure 6. Coefficients' posterior distributions

Figure 6 illustrates the posterior distributions of the constructed model on an interval plot. The thin blue lines represent the probability mass that is outside the highest credible zone, whereas the thick blue lines indicate the probability mass contained within the 89% Highest Posterior Density Intervals. (HPDI). As seen in Figure 6, the 89% HPDI of *Homeaesthetic*, *PlantDiversity*, and *PlantDiversity*Homeaesthetic* are completely distributed on either the positive or negative side of the axis. This suggests that the estimated results of these coefficients are highly reliable. However, a proportion of the distributions of *AnimalDiversity* and *AnimalDiversity*Homeaesthetic* is still located on the opposite side of the axis, implying that the effect of *AnimalDiversity* on *BioLossBelief* and the moderation effect of *Homeaesthetic* on the relationship between *AnimalDiversity* and *BioLossBelief* are weakly reliable.

Employing Equation (1.2) and the estimated mean values of parameters in Table 2, we calculated degrees of biodiversity loss belief. For clarity, the estimated degrees of biodiversity loss belief based on plant and pet diversity are plotted in Figures 7-A and 7-B, respectively. Both Figures suggest that the effects of plant and pet diversity on urban residents' biodiversity loss share a similar pattern. To elaborate, for urban residents who felt their houses' aesthetic due to plants/animals, the diversity of plants or pets does not affect the biodiversity loss belief. For those who did not feel their houses aesthetic due to plants/animals, the diversity of plants or pets positively affects the belief. Nevertheless, the effect of plant diversity is more significant and clearer than that of pet diversity.

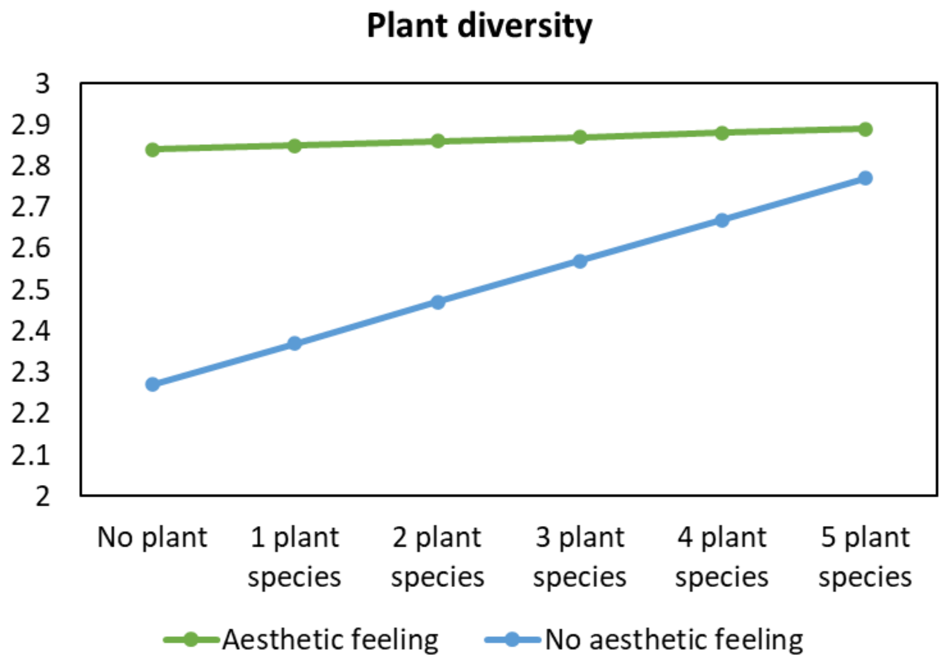

Figure 7-A. Estimated degrees of biodiversity loss belief of urban residents who own a plant but not a pet

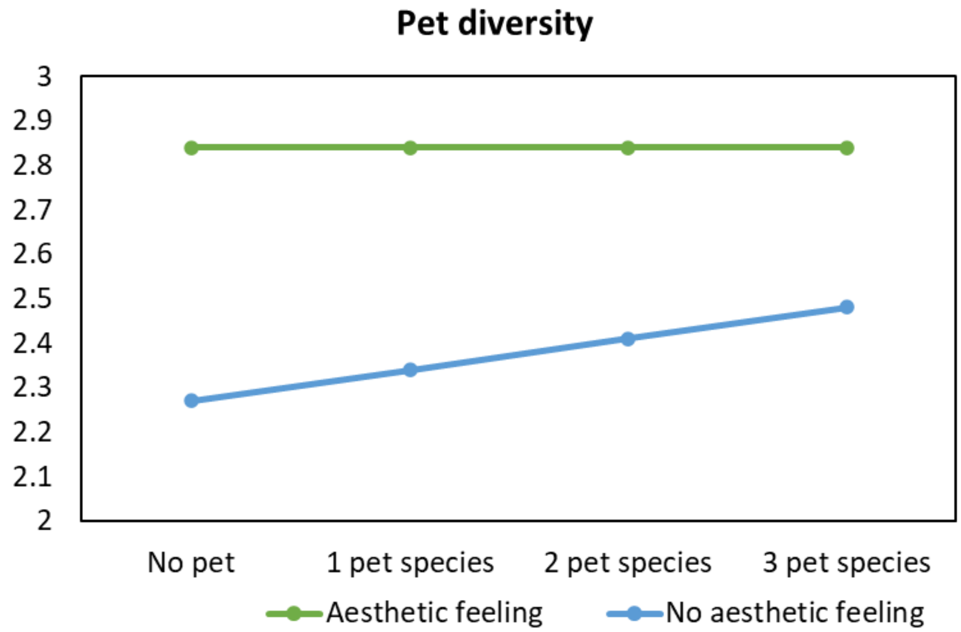

Figure 7-B. Estimated degrees of biodiversity loss belief of urban residents who own a pet but not a plant

4. Discussion

Using the Bayesian Mindsponge Framework (BMF) analytics on a dataset of 535 urban residents, the current study found that the aesthetic feeling induced by plants/animals positively influences the belief in the occurrence and significance of biodiversity loss. The positive effect of aesthetic feeling induced by plants/animals supports our assumption that urban residents' aesthetic experience contributes to the information multi-filtering process. When the aesthetic feeling is positive, it will add more perceived value to pet- or plant-related information (including biodiversity-related information) in the subsequent information-seeking, -selecting, and -filtering processes, making urban residents more likely to recognize the occurrence and significance of biodiversity loss. The finding is also aligned with previous research, which underscores the positive influence of aesthetic experience on environmental values and the intention of pro-environmental behavior (Li et al., 2022; Mtutu & Thondhlana, 2016; Wang & Yu, 2018).

We also found the positive effect of the diversity of plants and pets on the biodiversity loss belief. Still, the effect is conditional on the urban residents' aesthetic feeling of the house induced by plants/animals. Specifically, the diversity of plants and pets only positively affects biodiversity loss belief when urban residents feel that their houses' aesthetics are negatively affected by plants/animals. However, species diversity has no significant impact for those with positive aesthetic feelings. The positive effect of species diversity on biodiversity loss belief when urban residents have a negative aesthetic feeling induced by plants/animals can be explained through the information-processing lens of Mindsponge Theory (Vuong, 2023).

The theory suggests that individuals are more inclined to absorb information that resonates with their existing core values (or highly trusted information). Aesthetics is not the only ecosystem service that is provided by the diversity of plants and pets, so people might perceive other benefits other than aesthetics. Although the negative aesthetic feeling induced by plants/animals can make people less likely to absorb biodiversity-related information, other perceived benefits of plant and pet diversity might offset this effect. Studies have suggested that pet ownership and home gardening can result in multiple advantages, such as favorable physical outcomes, improved mental health, connection to nature, place attachment, attention restoration, etc. (Kaplan & Kaplan, 1989; Kruger et al., 2014; Raymond et al., 2019; Samus et al., 2022; Wood et al., 2015; Zhang et al., 2021). Besides these advantages, the hypothetical biophilia, which assumes that humans have an innate tendency to seek connections with nature and other life forms, might also be applicable in this situation (Kellert & Wilson, 1995; Wilson, 1986). Perhaps biophilia exists in people's mindsets or has been reinforced through genetic information over thousands of years surviving and evolving within the natural environment, making them more likely to recognize the benefits provided by plant and pet diversity (Barbiero & Berto, 2021; Nguyen, Le, et al., 2023). Due to such offsets, people with negative aesthetic feelings about their houses are still likely to absorb more biodiversity-related information when they access a higher level of plant and pet diversity. Despite the explanation above, it remains unclear why species diversity does not affect the belief when urban residents possess the positive feeling about their houses' aesthetics. Thus, future studies should be conducted to elaborate on this difference.

Notably, the effect of pet diversity on biodiversity loss belief is less significant and reliable than plant diversity's. This could be because plants are often perceived as more stationary elements in the environment, contributing to the overall ambiance without dynamic changes (Huey et al., 2002). Pets, conversely, are more energetic and active members of the living environment (Kateryna et al., 2023). Therefore, as the diversity of pet species increases, the task of pet care concurrently becomes more intricate and challenging, especially when those pets are exotic animals other than dogs and cats. The house's cleanliness and tidiness will be negatively affected without adequate management, adding the perceived costs of pet diversity into the urban residents' mindset. These perceived costs might subsequently make the effect of pet diversity on the absorption of biodiversity-related information less consistent and more subject to context. For example, Nguyen, Nguyen, et al. (2023) found that when urban residents feel comfortable at home, they are more likely to believe in the occurrence and significance of biodiversity loss as the pet diversity increases. Nevertheless, when urban residents feel uncomfortable, pet diversity is negatively associated with their biodiversity loss belief.

Based on the current study findings, we suggest that enhancing the house's aesthetics through in-house planting or pet ownership can be a crucial way to improve urban residents' belief in the occurrence and significance of biodiversity loss. When urban residents recognize that biodiversity loss is real and can cause severe consequences to their lives, they will be more likely to seek and absorb information associated with biodiversity conservation, which gradually helps build up the eco-surplus culture among urban residents (Nguyen & Jones, 2022a; Vuong, 2021). As urban residents are often perceptually disconnected from nature, the eco-surplus culture will help safeguard them from the environmental crisis and extinction denialism and improve their willingness to support pro-environmental actions and policies. Even when the aesthetics cannot be achieved, increasing the urban residents' connections to biodiversity by planting more types of plants in the house can also help raise their belief in biodiversity loss and subsequently build up the eco-surplus culture.

Although the influence of education and prior experience on aesthetic appreciation of natural landscapes and properties has not been tested, it is evident that aesthetic appreciation in arts is significantly influenced by complex webs of meaning derived from their self-hood, personal experience, and socio-cultural surroundings (Carlson, 2005; Harland et al., 2000; Jorgensen, 2011). Thus, increasing opportunities for interacting with nature (e.g., pets, plants, public parks, nature-based recreation) and environmental education can be a good strategy to shape urban residents' aesthetic perception. Implementing the strategy effectively might lead to a loop of aesthetic experience, eco-surplus culture, natural conservation, and biodiversity (Nguyen & Jones, 2022a; Tribot et al., 2018; Vuong, 2021). This strategy is especially applicable and essential for young generations that are born and nurtured in urban areas, as they are the populations that have limited interactions with the natural environment but will be responsible for environmental decision-making in the future (Vuong, 2020a).

The study is not without limitations, so we present them here for transparency (Vuong, 2020b). Firstly, the study's emphasis on urban areas in Vietnam may restrict the findings' applicability to other urban areas in different countries and rural settings. The establishment of causal relationships between variables like plant diversity, aesthetics, and beliefs about biodiversity loss is also hindered by a cross-sectional dataset collected at a particular time. There are concerns about the long-term impacts of exposure to varied plant species and aesthetic improvements on pro-environmental actions, given the study's focus on belief about biodiversity loss. Future research has the potential to provide a more thorough investigation of these relationships and their implications for urban conservation efforts by incorporating various populations, using longitudinal designs, and considering confounding factors.

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