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The Effect of Biodiversity on Green Space Users' Wellbeing—An Empirical Investigation Using Physiological Evidence

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Abstract: Promoting ecological health and human wellbeing are two fundamental goals in landscape sustainability. Green spaces are thought to improve users' psychological and physical wellbeing through the contact with nature. However, the results of some studies that rely on self-reports suggest that when the level of naturalness in a green space reaches a certain point, the beneficial effects diminish and in some cases can cause negative responses. We explored this possibility through an experimental study in which we use physiological measures rather than perceptions to assess people's wellbeing. We investigate how people are affected by outdoor settings with varying degrees of biodiversity and whether the correlation between biodiversity and physiological wellbeing is negative or positive. We used multiple measures of insect diversity as an indicator for biodiversity, and biofeedback measures as indicators of wellbeing. Our findings suggest that people are equally affected by more biodiverse and less biodiverse settings. Physiological responses remain largely unchanged when biodiversity increases. This suggests that settings rich in biodiversity will not negatively influence people's physiological wellbeing, and designers and city planners should not hesitate to use ecological best practices in their designs.

Keywords: biodiversity; biofeedback; conservation; wellbeing; sustainability

1. Introduction

At the foundation of landscape architecture are two essential cornerstones of sustainability. First, landscape architects strive to create landscapes that support ecosystem health. This is a challenge in part because as urban growth surges, we see increased habitat loss, reduced biodiversity, increased pollution, and increased global warming. A second essential goal of landscape architecture is to create landscapes that support people, especially those living in cities with limited green space. This is a challenge because the demands of modern life place considerable strain on urban residents. Fortunately, natural landscapes—even small amounts of natural landscapes—can help people feel relaxed and restored.

These two landscape goals—promoting ecological health and promoting human wellbeing—are often approached from one side or the other. Is it possible, however, that green space can meet the needs of both human wellbeing and ecological health? There is reason to believe this may be a challenge [1–3]. A number of studies have shown that people's preference for settings turns from positive to negative when the naturalness of the place exceeds a certain threshold [4–6].Those negative perceptions can include, for example, a sense of fear and disgust [1–3]. Yet there are hints that more ecologically healthy settings are positively associated with wellbeing. Fuller et al. [7] measured the impact of biodiversity and subjective wellbeing and found a positive relationship between species richness and perceived self-reflection or self-identity. Indeed, several studies suggest there is ample reason to integrate measures of ecological health and human wellbeing [8–10].

Studies examining the impact of the ecological health of a setting on humans have primarily used perceptions of wellbeing, rather than physiological measures. As a result, we do not have enough evidence about human's physiological responses to nature-rich, biologically diverse environments [11,12]. When measures change from perception to physiological measures, are the results similar or different? To what extent does a higher level of naturalness negatively impact people's physiological responses? To what extent is it necessary to reduce naturalness—and thus ecological function—to avoid the possible negative effects on people?

In this study, we examine the impacts of varying levels of biodiversity in landscapes on physiological measures of wellbeing. Biodiversity is vital to a landscape's ecological health. We used a clinical-grade biofeedback instrument to investigate the extent to which differences in ecological naturalness produce differences in emotion-related physiological responses in people. We examined four indicators of biodiversity: richness, abundance, diversity, and evenness and examined the relationship among these measures and three objective measures of biofeedback response: facial muscle tension, heart rate variability, and blood volume pulse.

The central aim of our research is to gain insight into the relationship between exposure to landscapes that vary in terms of biodiversity and people's physiological wellbeing. Without understanding this relationship, urban designers may wonder what trade-offs they will have to make to promote both ecological and human health and wellbeing. Designers and planners seeking to promote sustainability through increased biodiversity need to know the answers to these questions to ensure that their designs benefit the natural environment and the people they serve.

2. Literature Review

2.1. Integrating Ecological and Human Health

As urban growth increases across the earth, scientists have observed degraded ecosystems [13,14] and a disconnection of people from nature. Indeed, humans are innately sensitive to other species and lifelike processes, and people have a need to connect with nature [15,16]. This connection plays an important role in people's wellbeing, impacting our emotional, spiritual, aesthetic, and cognitive development [17].

The concept of sustainability recognizes that humans are an integral part of the ecosystem, and that accordingly, a properly managed environment must be ecologically and socially sustainable [18]. More than half of the global population lives in urban environments [19]. Urban residents seek opportunities to visit green spaces for relaxation and restoration through contact with nature.

Our ancestors responded to environmental cues around them and sought out settings where they could avoid danger and increase their chances for survival. Even today, humans are sensitive to environmental cues, and they respond in positive physiological and psychological ways when they are in contact with nature [20]. Environmental cues often create physiological responses in humans. For example, studies have determined that natural scenery promotes more positive physiological reactions than non-natural elements, supporting stress reduction and faster recovery from medical procedures [21–23]. Compared to completely human-made settings, settings with water or green elements promote psychological benefits [24–30].

Natural elements in landscapes have been shown to help restore people's ability to pay attention, an ability that is essential to managing distractions and focusing on a task. In their Attention Restoration

Theory (ART), Kaplan and Kaplan [4] argued that the ability to pay attention requires effort and therefore fatigues occurs over time. When people are constantly working under pressure or are engaged in tasks that require continuous directed attention, such as months of solid effort on a project, an intense workday, or a sustained period of worry, they experience mental fatigue. Mental fatigue occurs frequently in urban environments and can lead to a weakened ability to focus, impatience, poor judgment, frustration, and increased irritability, which may trigger aggression [4]. The stimuli in a natural environment provides "soft fascination", attracting people's involuntary attention and replenishing their directed attention [26].

While many studies exploring the impact of nature on health and wellbeing have used psychological or subjective measures of wellbeing, only a few have used physiological measures. Physiological measures, in contrast to psychological measures, detect objective responses of the human body and can provide rich evidence about how the body responds to nature. Ulrich's Stress Reduction Theory [31–33] focused on the physiological and involuntary reactions of the limbic system to surrounding landscapes [32,33]. When an individual has contact with natural environments, the autonomic nervous system of the brain and muscles produces physiological responses, including relaxed muscle tension, reduced blood pressure, and a lower pulse rate.

Biofeedback is a physiological indicator of wellbeing that uses "information generated by involuntary functions of the central or autonomic nervous system, obtained by techniques that use monitoring devices" [32,33]. Hartig et al. [22] used biofeedback measures along with psychological instruments to compare the effects of urban and natural features. Their findings indicated that exposing individuals to natural settings reduces high blood pressure related to emotional stress and anger. Ottosson and Grahn [34] used attention tests, blood pressure, and heart rate to evaluate the effects of outdoor gardens in long-term care facilities. They argued that being in outdoor gardens consisting of trees and grasses significantly improves concentration, but no effect on blood pressure or heart rate was found. Chang and Chen [35] used blood volume pulse and brain waves to investigate the impact of window views and indoor plants on anxiety levels in the workplace. They found that participants had lower blood volume pulse with a view of nature or with the inclusion of indoor plants in their surroundings.

In this study, we use biofeedback measures (heart rate, blood volume pulse, and facial muscle measurements) as indicators of wellbeing.

2.2. Concept and Measures of Biodiversity

Biodiversity is a key indicator of ecological health and an important aspect of sustainable development. Biodiversity can be measured by indices that use mathematical expressions to represent the composition of biological communities in an area. Based on the parameters used (e.g., the number of species or the number of individuals), these indices measure different characteristics of a particular biological community, habitat, or ecosystem type [36]. Ecological indices, such as abundance, richness, diversity, and evenness, represent a unique ecological definition; for example, "species richness is the number of species from a particular taxon or life form (e.g., insects or birds), and the concept of diversity is the combination of the communities' richness and evenness" [36].

A selection of a particular taxon is essential for measuring ecological diversity. Insects have been shown to be suitable subjects for landscape research because their community characteristics can reflect the general ecological status of their habitats [37,38]. While insects inhabit diverse environments, their choices of habitats differ among species based on their morphologic and physiologic characteristics [39]. Insect assembly can be sensitive to patch quality, spatial complexity, vegetation form, and resource diversity for survival activities such as feeding, resting, and hiding [40,41]. In addition to these factors, many variables can also influence insect assembly, including the dispersal, age, and succession phase of the setting. Habitats such as forestry edges and openings, as well as bodies of water with adequate sunlight and vegetation, often attract an aggregation of insects. Prime forests, which promote natural succession, often sustain more abundant insects than planted forests [42].

Insects have been identified as an appropriate indexing class to monitor environments due to their ability to adapt to environmental change and reflect a habitat's attributes to their assemblies [43–45]. In addition, insects can be observed at little cost, and provide an objective measure of the ecological health of an urban green space.

In our research, we will be investigating ecological health by conducting a field survey with insects as the target taxon and will use the ecological indicators that characterize species richness, abundance, diversity, and evenness to measure the landscapes' ecological biodiversity.

3. Methods

To assess the relationship between biodiversity and physiological wellbeing, we examined the extent to which biodiversity is negatively or positively correlated with physiological wellbeing.

The ecological surveys and wellbeing experiment were conducted in outdoor settings in Taiwan. The ecological surveys used insects as the indicator of biodiversity. The ecological data were collected in 60 sample plots in three regions. The collected insects were identified in an entomology lab and were used to calculate the biodiversity indices.

The wellbeing data were collected through objective measures of physiological responses. Participants were conveniently recruited on site and joined the experiment voluntarily and anonymously. Investigators used portable nonintrusive sensors to monitor and record the data. Three biofeedback measures (muscle tension, heart rate, and blood volume pulse) were employed as wellbeing variables. The study areas, measurements, devices, and procedures are described below.

3.1. Study Areas

To select study areas, we examined 60 sample plots in three locations in Taiwan. The sample plots were representative of common recreational green spaces in Taiwan and were easily accessible to the general public via roads or trails. Ecological conditions varied among the three locations: Taipei (lat. 25.017, long. 121.533), Nanchung (lat. 24.697, long. 120.999), and Wulai (lat. 24.866, long. 121.547). The sample plots are in a sub-tropical region where the highest temperature is approximately 38 °C from June to August and the lowest temperature is approximately 10 °C from January to March. Each sample plot was a radius of 100 m [46–48] and was at least 100 m from another plot to avoid overlap.

The first location, National Taiwan University, Taipei, is an educational institution consisting of approximately 52 hectares. The large, mixed-use urban green space around the University is used by the public and is surrounded by commercial and residential areas. The sample plots in this location mainly consist of landscaped areas that include elements of trees, shrubs, water features, semi-natural grasslands, lawns, sidewalks, paved roads, and walking trails located between buildings.

The second location, Sanshan, is known for its abundant natural and cultural recreation resources. The landscape of this area has both suburban and rural/farming characteristics. The land use is a mixture of patchy farmland with semi-natural vegetation consisting of trees, bushes, grasslands; water features; and scattered residential buildings, trails, and roads.

Finally, Wulai is a mountainous area, known for its rich natural and cultural resources and primitive atmosphere. The landscapes primarily consist of naturally grown trees with multi-level shrubs, interspersed creeks, grasslands, and trails for outdoor hiking.

The sample plots were accessible to the public and available for experimental studies (Figures 1 and 2). Investigators gathered two sets of data in each sample plot: ecological surveys of insects and participants' biofeedback measures of heart rate, blood volume pulse, and facial muscle. The following sections describe each data set and participants in the study.

(**a**) (**b**) (**c**)

Figure 1. The selected aerial photos demonstrate the general environments of study plots within the following regional locations: (**a**) National Taiwan University; (**b**) Nanchung; (**c**) Wulai.

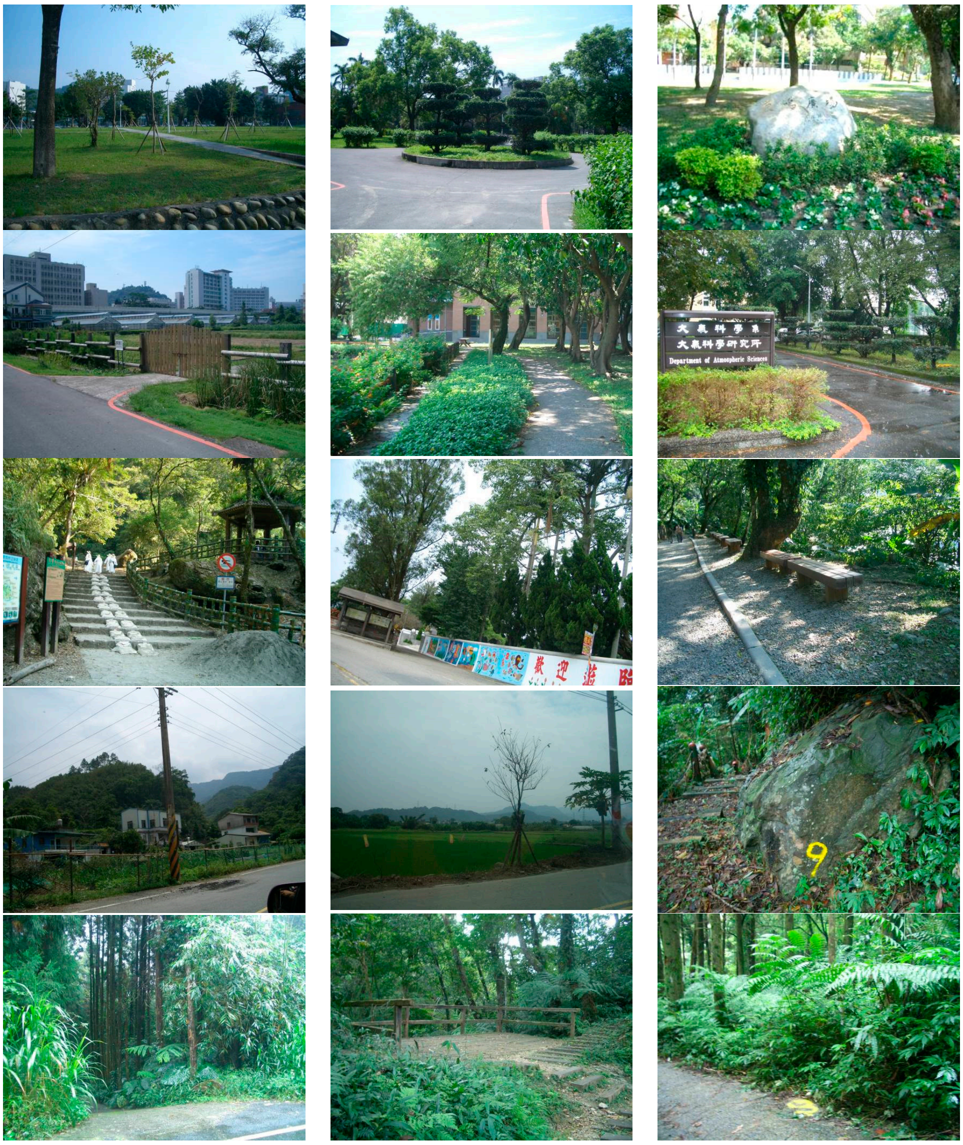

Figure 2. Selected photos demonstrate the variation of plot surroundings.

3.2. Field Survey—The General Biodiversity Data

We used insects as an indicator of biodiversity. The insect data were collected using a modified line-transect method and sweep-net technique [46–48]. Each sample plot was divided into four equal quadrants. Starting from one of the four intersections of the quadrant dividing lines and boundary, a trained surveyor walked back and forth throughout the quadrant, sweeping a plastic-meshed butterfly net across the landscape in a horizontal figure-eight pattern. The surveyor then repeated the procedure for the remaining three quadrants to complete the survey of the study plot.

The surveyors then recorded the observed insects. The collected materials were taken to the entomology laboratory at National Chung Hsing University for identification. All study plots were surveyed with an identical protocol on sunny or fair days three times in November, February, and April.

The survey data were used to calculate ecological indicators and to illustrate taxa composition and community dynamics for each plot, including richness, evenness, abundance, and diversity. These indices are defined in Table 1 below.

Table 1. Definitions and value meanings of the ecological indices.

Biodiversity Index	Definition	Meaning of Values
Richness	The number of different species in a study plot	The number of species. The larger the value, the more species found in the plot.
Abundance	The number of individual insects in a study plot	The larger the number, the more individuals found in the area.
Diversity	$H' = -\sum_{K=1}^{S} P_k \log_2 P_k$. ($P_k$) is the proportion of individuals in the ith species. (S) is the number of species	Diversity indicates the characteristics of an insect community based on the Shannon-Wiener diversity index. The larger the number, the greater the diversity.
Evenness	$j' = H'/\log_2^S$. (S) is the number of species. (H') is community diversity (Shannon-Wiener diversity index)	Evenness indicates the equality of abundance in an insect community measured by the proportion of insect orders in a study plot, meaning the relative evenness among species. A greater number indicates more equal proportions of species in a study plot.

3.3. Field Survey—Physiological Data

We used physiological data from a biofeedback instrument to objectively measure wellbeing. The three biofeedback indicators used were electromyography (EMG), cardiovascular heart rate (HR), and photoplethysmograph/blood pulse volume (BVP) [33,49]. EMG measured the electrical activities of muscles; higher readings from the EMG indicate greater levels of stress. In comparison to postural muscles, the facial muscles on the forehead are more sensitive to changes in the physiological reactions of mental and emotional tension caused by visual stimuli [50,51]. In response to stimulation from their environment, individuals have emotional reactions that affect the facial muscles and thus generate differences in electronic potential [52].

For EMG data collection, three electrodes were placed 4 cm (1.6 inch) above the eyebrows and outside the frontalis muscle. To measure the potential differences, reference data were collected using an electrode placed in the middle of the forehead (Figure 3).

The other two biofeedback measurements—heart rate and blood volume pulse—are managed by the sympathetic and parasympathetic nerve systems, which indicate vasomotor activity and sympathetic arousal [53]. An infrared pulse sensor was placed on the index fingertips of the non-dominant hand and stabilized using medical tapes after the removal of possible residuals with an ethanol wipe (Figure 3). Identical procedures were applied to the subjects in the different sample plots. EMG, HR, and BVP values decrease as when the level of relaxation increases; increases in these values indicate increases in stress level.

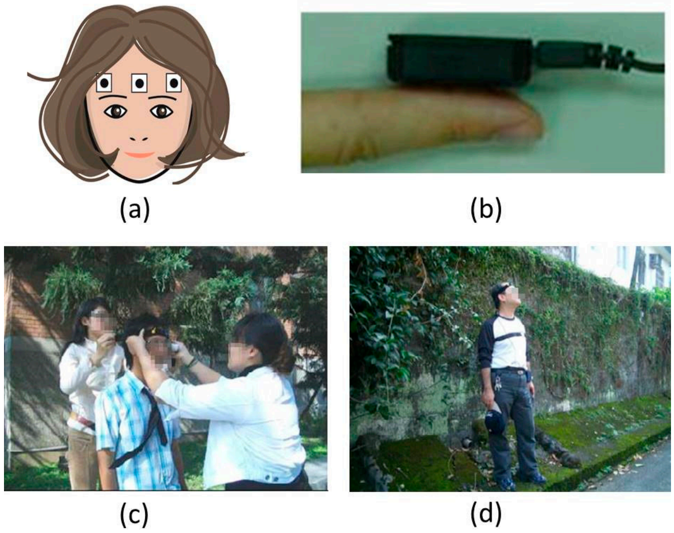

Figure 3. Placements of biofeedback sensors: (**a**) electromyography (EMG); (**b**) heart rate (HR); and blood volume pulse (BVP); (**c**) attaching biofeedback equipment (**d**) during biofeedback data collection.

3.3.1. Procedure

Our experimental procedures followed the guidelines developed by Cacioppo et al. [54]. Before collecting data, we explained the procedures to the participants. Participants were then asked to take a comfortable position and relax for 5 min before we placed the biofeedback sensors on their skin. At this point data collection began as we asked participants to close their eyes for 10 s and relax. Then, they opened their eyes, observed the surrounding environment for 1 min, then closed their eyes again and relaxed for another 10 s. The duration of biofeedback data collection was 1 min and 20 s for each participant (Table 2). The last 40 s in the 'open eye' time was extracted and the values from this period were subtracted from the initial EMG, BVP, and heart rate values for further analyses.

Table 2. Biofeedback data collecting procedures.

Time	Activity	Biofeedback Monitoring
5 min	• Procedure orientation. • Biofeedback sensors placement.	No
10 s	• Initial baseline EMG, HR, and BVP values recorded. • Subject closes eyes and relaxes.	Yes
1 min	• Subject opens eyes and views the surrounding environment.	Yes
10 s	• Subject closes eyes and relaxes.	Yes
5 min	• Removal of biofeedback sensors.	No

3.3.2. Participants

Individuals were recruited for voluntary and anonymous participation at the study sites. Once the participants had agreed to participate in a nonintrusive biofeedback survey, they were taken to the center of one of the sample plots where the biofeedback measurements were taken. While the settings were not completely silent, there were no sharp or loud sounds during the experiments.

The number of valid biofeedback responses totaled 151 from the 60 sample plots. Among the participants, the gender composition was 46.8% female and 52.6% male. The majority of participants were between 18–45 years old (85%) and 15.1% were over the age of 45. In the 18–45 year age group, half were between the ages of 18 and 25 (42%), another half were between the ages of 26 and 45 (42.9%).

3.4. Statistical Analysis

Descriptive statistics regarding the sample are shown in Table 3. To test the research questions, the Pearson product-moment correlation coefficient was calculated to measure the strength of the relationship between the pairs of variables.

Table 3. Descriptive statistics of physiological responses and biodiversity indicators (Sample plots: 60, valid respondent: 151).

Physiological Responses	**Mean**	**Std.**	**Max.**	**Min.**
EMG difference	6.75	33.22	378	−120
HR difference	1.18	11.14	32.40	−32.44
BVP difference	−0.13	1.83	7.28	−9.96
Biodiversity Indicators	**Mean**	**Std.**	**Max.**	**Min.**
Richness	8.49	1.88	13	4
Abundance	237.46	213.85	1563	50
Diversity	2.05	0.38	2.83	1.3
Evenness	0.68	0.11	0.90	0.44

The biofeedback indices of muscle tension (EMG), heart rate (HR), and blood volume pulse (BVP) were entered as variables and correlated with biodiversity indices of insect richness, abundance, diversity, and evenness in the analyses. The Pearson's correlations were calculated in the Advanced Statistic Module of SPSS Statistics.

4. Results

In this section, we report the results of the relationship between biodiversity and people's wellbeing. There were two data sets used in the analyses: ecological data and wellbeing data from physiological responses. Biodiversity was measured using a set of ecological indicators expressing the characteristics of insect assemblies. Wellbeing was measured using biofeedback measures of muscle tension, heart rate, and blood volume pulse.

4.1. Descriptive Statistics

After collection and species identification, the insect data of each sample plot were calculated based on the expression of ecological indicators. In the biodiversity survey, a total of 15,960 individual insects were found and 14,014 of them were identified to, at least, the order level. The first five orders with the largest number of individual insects were *Homoptera* (32.36%), *Diptera* (26.76%), *Hymenoptera* (12.72%), *Lepidoptera* (10.79%), and *Thysanoptera* (8.58%). Among the biodiversity indicators, the range of richness was approximately three times. The values of diversity and evenness showed relatively less variation than the values of richness and abundance.

In the physiological dataset, the mean values of EMG, HR, and BVP differences indicate the levels of physiological variation before and after the treatment. From the three biofeedback data sets (muscle tension, heart rate, and blood volume pulse), we extracted data at two time points—before and after the treatment. Next, we calculated the mean value of the differences between the two time points. The mean value of EMG difference (6.75) and its standard deviation (33.22) indicate a relatively large variation among subjects' responses and a similar variation occurs in the HR data set. The BVP differences show less variation than the EMG and HR differences.

4.2. Relationship between Biodiversity and Physiological Responses

In this section, we report the associations between biodiversity and physiological biofeedback responses. First, we ask how people are affected by differing degrees of biodiversity. Second, we see whether green spaces supporting higher biodiversity are negatively or positively correlated with physiological responses. To answer these questions, a Pearson product-moment correlation coefficient was computed to assess if the physiological responses of people correlate with changes in biodiversity.

The extracted biofeedback variables and calculated biodiversity variables were entered into the statistical computation of the Pearson product-moment correlation coefficient. Scatter plots were also generated to summarize trends of the relationship between pairings of biodiversity indicators and physiological responses (Figure 4).

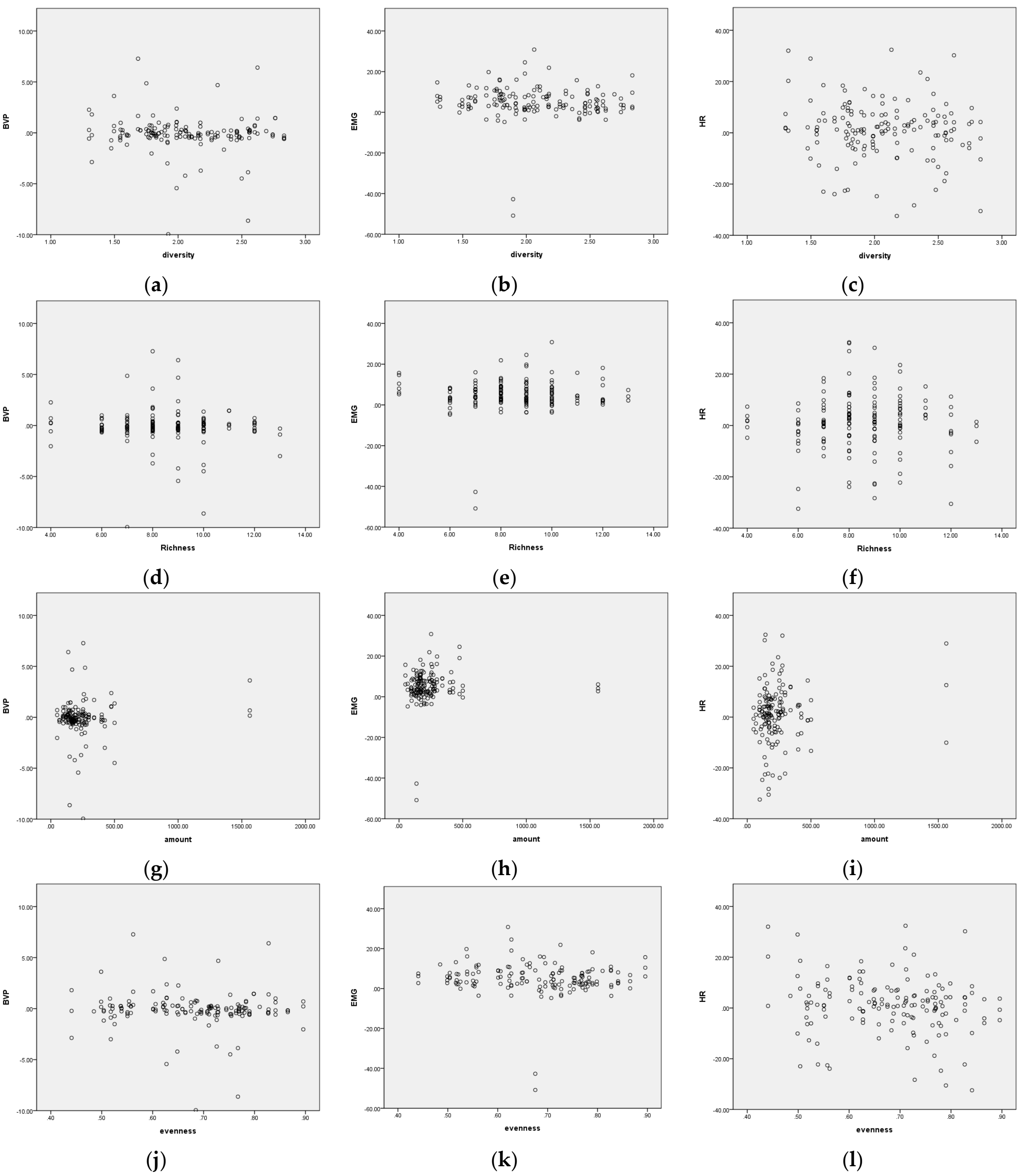

Figure 4. (**a**–**l**) Scatter plots of each pair of variables. (**a**) Diversity vs. BVP; (**b**) Diversity vs. EMG; (**c**) Diversity vs. HR; (**d**) Richness vs. BVP; (**e**) Richness vs. EMG; (**f**) Richness vs. HR; (**g**) Abundance vs. BVP; (**h**) Abundance vs. EMG; (**i**) Abundance vs. HR; (**j**) Evenness vs. BVP; (**k**) Evenness vs. EMG; (**l**) Evenness vs. HR.

Most pairings showed no significant correlation (Table 4), indicating that physiological responses of wellness did not change significantly as biodiversity in an environment increased. Diversity, richness, and abundance did not correlate with other physiological responses, suggesting that greater biodiversity in a landscape did not significantly influence physiological measures of wellbeing. Importantly, ecologically diverse settings were not negatively correlated with wellbeing through physiological measures.

Table 4. The correlation metrics of each pair of variables.

		EMG	BVP	HR
Richness	Pearson correlation	0.065	−0.056	0.002
	Sig.	0.426	0.490	0.982
Abundance	Pearson correlation	−0.030	0.100	0.137
	Sig.	0.714	0.218	0.092
Diversity	Pearson correlation	0.108	−0.070	−0.121
	Sig.	0.184	0.390	0.136
Evenness	Pearson correlation	0.080	−0.053	−0.163 *
	Sig.	0.324	0.515	0.043

n = 151, * $p < 0.05$.

The findings of Pearson's correlation show that the biodiversity indicator of evenness is the only indicator that is significantly, yet moderately, correlated with a physiological response—heart rate (r = −0.163, n = 151, p = 0.043). This result indicates that environments with higher species evenness prompted a slightly greater calming effect, as indicated by a lower heart rate. Although the settings that support ecological evenness are likely to provide a moderate calming effect, people are generally affected equally by settings that support the ecological characteristics of richness, abundance, and diversity and those that contain less biodiversity.

5. Discussion

Landscape architects need to know the relationship between biodiversity and human wellbeing so that they can design settings that serve both nature and people. People can be ambivalent toward nature, perceiving it to be "both beautiful and terrifying, both awesome and awful" [55]. We know that people respond in both positive and negative ways when exposed to green environments, until the findings presented here, we did not know how biodiversity in these settings affects people's physiological responses. This study answered the following questions: To what extent are people's physiological responses affected by differing degrees of biodiversity in green spaces? Are biodiverse settings positively or negatively correlated with wellbeing? In outdoor field settings, we collected empirical data on ecological biodiversity and physiological responses using biofeedback measures (EMG, HR, and BVP) and biodiversity indicators (richness, abundance, diversity, and evenness).

We found that, for the most part, people are equally affected by more biodiverse and less biodiverse settings. The majority of physiological responses remain unchanged with increases in biodiversity. The only significant relationship was between heart rate and ecological evenness, though the effect was small. Heart rates were slightly lower in settings where there was more ecological evenness (settings that contained more uniformity in the number of members of different species). Importantly, settings that were more diverse were not correlated with decreases in physiological responses. Settings that are more biodiverse seem to be no less beneficial to people's physiological wellbeing than less biodiverse settings.

This study adds to a growing body of research that has found physiological and psychological benefits from contact with nature. These studies suggest that people are biophilic—that is, they are instinctively bonded to other living systems. The therapeutic function of environments with varying levels of biodiversity may be elicited through both passive involvement (e.g., viewing natural scenery) and active participation (e.g., hiking). In natural settings, people can experience freedom from social constraints [55] and physiological and mental health benefits [9].

It may seem surprising that increases in biodiversity did not lead to negative physiological responses. We offer three possible explanations. First, we suggest that biodiversity may not be the main cause of apprehension in a landscape. Studies suggest that feelings of fear or sense of safety influence responses to an environment [1,3,4,6,23]. In our study, we controlled for safety by choosing study plots that are easily accessible to the public by roads or trails. The plots were located near buildings or other settlements, and investigators were on site, which may have increased participants' sense of safety. This may have led them to tolerate higher levels of biodiversity and complex forms of vegetation.

Although some studies found that people were more apprehensive in biodiverse settings, our results suggest that biodiversity may not be the main cause of apprehension in a natural landscape. Studies conducted in wilderness areas [55,56] found that people sometimes had negative psychological responses to nature because of fear of crime, encounters with wild animals, and concern about becoming lost in natural settings [57,58], or allergens from pollens and sap in some plants [59]. Studies conducted in urban or suburban spaces found that people feared natural areas when they felt vegetation could be used to conceal criminals [1–3,58]. We infer that the outer appearance and safety concerns may influence people's responses to an environment more than the inner ecological content or biodiversity of the place.

Second, it is possible that increases in biodiversity did not lead to decreases in physiological responses because we did not use settings that contained a wide range of biodiversity. In this study, we used common recreational green settings that the public can easily access. These settings were not forest preserves or ecologically protected areas. It is possible that settings with much higher or lower biodiversity are needed to generate significant differences in physiological responses. A biodiversity threshold may exist in order to produce significant effects in physiological wellbeing.

Third, it is possible that the findings may have been less dramatic because people can experience complex emotions in a natural setting (e.g., fascination and fear). Kaplan and others argue that negative emotions can "offset" positive ones, leading to a more neutral overall response [4,5].

Our study findings suggest that, with sound management, biodiverse setting do not negatively impact people's wellbeing. Designing ecologically healthy spaces where people can reap physiological and psychological benefits is a critical task. A number of evidence-based design criteria for creating such spaces have been published [60]. We make the following design recommendations.

First, landscape architects should not hesitate to use ecological best practices because in our study more ecologically healthy landscapes had no negative effect on people's physiological wellbeing. To make landscapes biodiverse, designers should consider the ecological health of an ecosystem in addition to the visual form of the landscape. For example, to increase evenness, designers can include more species of ground cover and trees, and make sure to sustain many different species rather than letting one or two species dominate. Professionals should design landscapes that consider the essential needs of the organisms in the habitat. This will mean including different types of plant species that provide shelter or food sources for different organisms. On a macro scale, designers should use the ecological principles of habitat heterogeneity, patch connectivity, and structure complexity to guide their planning and designs [61–64].

Second, professionals should make sure that the landscapes are places where people can participate in activities, relax, and enjoy nature. People are more likely to visit and enjoy places where they feel safe, and maintenance and management affect people's sense of safety. Establishing a feasible management and maintenance system in the planning and design phases is critical in establishing the long-term success of the project. To enhance a sense of safety in ecological designs, designers can use partitions and have different levels of openness.

Green spaces are receiving significant policy attention as policy makers seek to restore environments that have been degraded by rapid urbanization. Policies also promote green spaces for urban dwellers who are increasingly sedentary and who suffer from stress and mental disorders [65]. For instance, current initiatives encourage children with attention deficit/hyperactivity disorder to have contact with nature as behavioral therapy [66,67]. Policies should continue to support green spaces for both ecological and human health reasons. To better integrate ecology and social science, conservation efforts require flexible strategies [68]. It is possible to balance ecological health and visual and sensational beauty in a shared landscape.

This study has some limitations. We measured the connection between biodiversity and wellbeing by focusing only on insects as an indicator of biodiversity and on the physiological indicators related to relaxation. We conducted this work in real settings that varied in terms of biodiversity but also in the amount of nature, and exposure to slight variations in sound, weather, and sunlight. Future research should include laboratory studies that isolate each of these variables and measure their independent contribution to health and wellbeing. Participants were recruited on site, and therefore may have already been reaping the physiological benefits of contact with nature, which may have influenced their physiological responses during the experiment. In addition, the time spent viewing nature during the experiment was small (only 1 min), and more time may be needed to produce a significant effect. In our study, we did not consider people's safety perceptions and emotional responses to the spaces. Future research should pair physiological measures of wellbeing with self-reported psychological measures.

Future research should also consider the shape of the dose-response curve of biodiversity and physiological and psychological responses. The sites in our study did not have very high or very low levels of biodiversity, and we need to know if scenes with higher or lower biodiversity continue to provide positive effects, or whether there is a point at which the physiological benefits start to decline. There may be a minimum or maximum threshold necessary for positive or negative effects to occur. Future research should also manipulate biodiversity along a fine-grain continuum so that we gain a better understanding of the levels of biodiversity necessary to influence health and wellbeing [69].

6. Conclusions

Ecological diversity is an important goal for establishing sustainable, equitable landscapes. We need to create landscapes with ecological richness and diversity and can rely on designers and planners to help achieve this goal. The most encouraging finding from this study is that people do not respond in negative ways to ecologically diverse landscapes. This finding frees designers and planners to create landscapes that are ecologically diverse. Further collaboration among stakeholders and a better understanding of the interactions between healthy urban ecosystems and human health are certainly desirable. Findings from such research are necessary as we live in an increasingly urbanized world where ecosystem health and human health are increasingly intertwined.

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Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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