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Article

Classification of Biophilic Buildings as Sustainable Environments

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Abstract: Biophilic design approach aims at creating favorable conditions for humans in various types of anthropogenic environments, while at the same time restoring broken human–nature connection. The biophilic design guidelines and principles are general and flexible and allow wide array of architectural expressions. In order to better understand the architectural expression possibilities provided by biophilic design approach, the existing classifications of biophilic architecture and biophilic design examples were analyzed with the aim to develop the classification that would reflect the links between a building's architectural expression and biophilic qualities. Three categories of biophilic architecture were distinguished in the developed classification: mimetic, applied, and organic. The distinguished categories were illustrated with the characteristic building examples and the evaluation of biophilic qualities and human-nature collaboration potential of these example buildings was carried out using comprehensive system of criteria. The analysis has demonstrated that all three distinguished categories—mimetic, applied, organic—allow for the creation of biophilic environments and hold the potential for human–nature collaboration, although organic biophilic design would be currently considered as the least developed, although most promising category.

Keywords: biophilia; biophilic architecture; biophilic building; classifications of biophilic design; human–nature collaboration

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1. Introduction

The term biophilia was coined as early as in 1964 by E. Fromm; however, it was developed and popularized in certain circles by biologist and naturalist and writer E. O. Wilson, who had developed and published in 1984, and later refined in his further works, what he has referred to as the biophilia hypothesis. According to this hypothesis, humans, as well as other species on Earth, had developed throughout their evolution and history surrounded by biodiversity and thus the interconnections with natural environment have persisted until this day [1–3]. The biophilia hypothesis states that human beings have an innate biological need to affiliate with nature; consequently, the biological diversity, the diversity of relations to nature, and diversity of landscape types are important for healthy human physical and psychological development [4]. Despite the benefits of connections with nature proven by environmental psychologists, medical researchers etc. [1,4], the human–nature connections and the biophilic qualities of our everyday environments continue to decline. Some researchers even identify our contemporary living environments as anti-biophilic [5]. According to A. Samalavičius [2], with the entrenchment of technologies and technological processes in human civilization, the human environment has strongly changed as well. Human habitats became closed and relatively sterile, even movement between locations happens in the closed environment of automobile. The mega-cities became inhospitable to nature and humans became distanced from their natural contexts, which has been their habitat for millennia. In order to restore broken human–nature connections and provide all the potential benefits of biophilic environments—the improvement of individual physical, psychological, and cognitive health and well-being as well as some social benefits like enhanced workers' productivity, improved public health, phytoremediation of industrial ruins [1,6]—the disciplines of biophilic design, biophilic urbanism, and diverse systems of criteria and patterns (for example, Kellert et al. [7]; Browning et al. [1], Salingaros [5]) that facilitate biophilic projects implementation have emerged. E. L. M. Wolfs [6] distinguished several characteristics of biophilic approach to design that differentiate it from other environmentally-oriented design concepts: positive focus on enhancing instead of minimizing and the potential for mutually beneficial human–nature collaboration. E. L. M. Wolfs [6] biophilic design focuses on the actualization and enhancement of nature's ability to improve the quality of human experience and well-being instead of focusing on minimizing negative human impacts, and strives to develop the link between artificial and natural processes based on symbiotic interdependence.

However, some challenges could be identified related with the increasingly growing trend of biophilic design. One of these challenges is identified by A. Samalavičius [2] as the paradigm of thinking entrenched by the architectural ideology of the last century. The other challenge is design superficiality, mentioned by E. L. M. Wolfs [6], when the biophilic commitment of the creators is limited to "videos of cats, the rounded edges of a mobile phone or the digital representation of natural material". The relevance of biophilic design and distinguished challenges encourage directing the attention of designers and researchers towards the peculiarities of biophilic architectural form, understanding better how architectural form can engender biophilic qualities or/and how biophilic features can be integrated into architectural form.

The aim of the research is to analyze the existing classifications of biophilic architecture and biophilic building design examples and to develop a classification that would reflect the links between building's architectural expression and biophilic qualities. The categories of biophilic architecture distinguished in the developed classification are illustrated with characteristic building examples and the evaluation of biophilic qualities of buildings is carried out using a comprehensive set of criteria. The methodology of the research includes an analysis of the literature and architectural design examples, a comparison and systematization, and an assessment of architectural designs according to predefined criteria. The relevance and novelty of the research are determined by the contemporary challenges of entrenched modernist architecture ideology and design superficiality and the proposed and elaborated classification of biophilic architecture, as well as the evaluation of buildings not only from the point of view of biophilic qualities, but also from the perspective of human–nature collaboration as possible responses to these challenges. The problems and difficulties in the context of this research were the need to grasp the diversity of expression of biophilic design into a limited number of categories as well as finding the categories that would reveal the synergistic relation between the expression of the building and its biophilic qualities.

2. Review of Present Classifications of Biophilic Design

In order to understand better the extent of biophilic design, it is important to delve into the ways that biophilic design applications could be classified and categorized. The review of existing classifications of biophilic design included a search of the literature on the subject of biophilic design in the scientific literature databases Web of Science, Scopus, and Google Scholar. The publications on the biophilic design of buildings [6–10], biophilic design principles [1,5,7–10], and biophilic urbanism [8] were reviewed and examined for existing classifications or distinguished specific categories of biophilic architecture. The analysis of the literature has revealed that first of all, with the growing understanding of the benefits provided by biophilic environments, efforts have been made to distinguish between biophilic and non-biophilic or "business as usual" designs or even anti-biophilic environments [5]. For this purpose, different systems of criteria [5] and patterns [1] were formulated. For example, the company Terrapin Bright Green has elaborated 14 patterns of biophilic design subdivided into three categories: nature in the space; natural analogues; nature of the space [1]. The analysis of the literature clearly reveals that biophilic design applications can be categorized according to scale (for example, biophilic building, biophilic block, biophilic street, biophilic neighborhood, biophilic community, and biophilic region [8]) or object (for example, biophilic interior design [9]). This research primarily focuses on the architectural expression of biophilic buildings. After reviewing the literature, several existing classifications applicable to architectural expression of buildings were distinguished in the biophilic design discourse: those inspired by nature and traditional design trends, historic and contemporary biophilic architecture, natural and artificial biophilic environments, and explicit and implicit biophilic design (Figure 1).

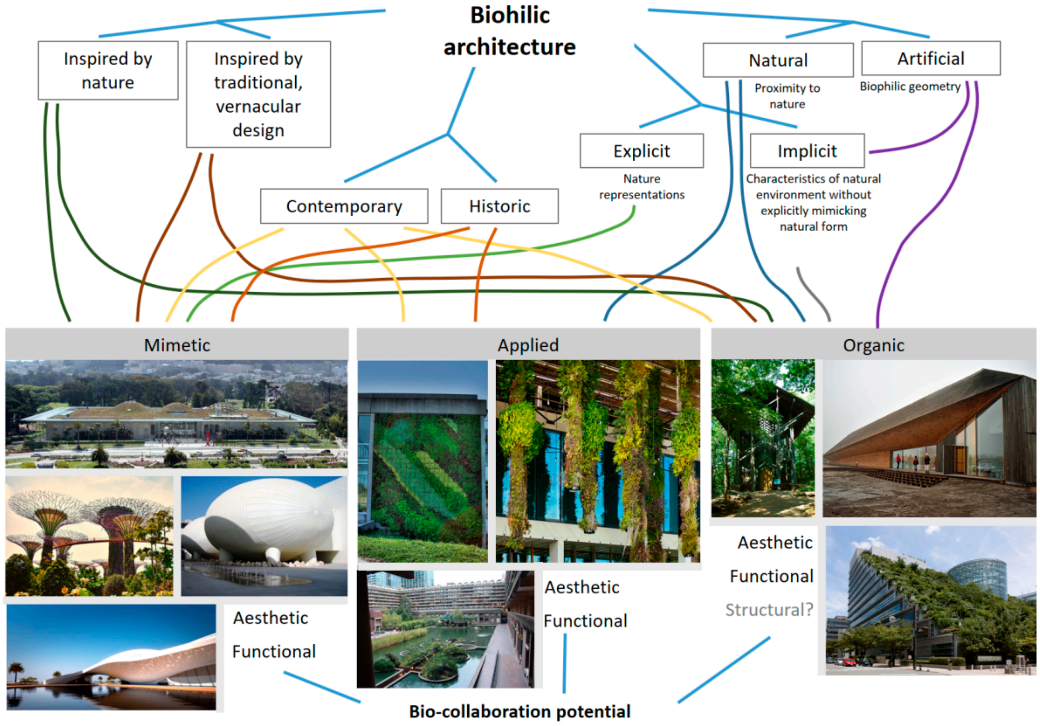

Figure 1. Existing classifications of biophilic architecture distinguished after a literature analysis and their links with proposed biophilic architecture categories: mimetic, applied, and organic. Each of three categories is illustrated by characteristic examples. Mimetic biophilic design: California Academy of Sciences (USA), Supertree Grove (Singapore), Weill Cornell Medical College (Qatar), BEEAH Headquarters (UAE). Applied biophilic design: green wall at Simon Fraser University (Canada), Perez Museum (Miami, Florida, USA), Khoo Teck Puat Hospital (Singapore), Barbican Estate (London, UK). Organic biophilic design: Thorncrown Chapel (USA), Wadden Sea Centre (Denmark), Acros building (Japan). All the images used in the illustration are from Wikimedia commons.

2.1. *Inspired by Nature and Traditional Design*

Two trends or dimensions towards which architects could orient the expression of biophilic buildings—inspired by nature, biological systems and natural shapes and inspired by traditional, vernacular, ethnic architectural forms, construction cultures and material applications—can be identified in the literature [7,10]. Both of these trends are generally characteristic for green design approaches since their inception and are identified in the book, Green Architecture by J. Wines [11]. For example, Snail House, designed by the Jersey Devil company in Forked River, New Jersey (USA) in 1972, is an example of architectural design inspired by nature [11]. S. Keller et al. identify Sydney Opera House designed by Jorn Utzon as inspired by natural shapes and forms [7]. An example of a building inspired by traditional design is the clay and straw Studio in the West Country, designed by David Lea (England) [11]. These broad trends allow conceptualizing biophilic shapes not only for natural and countryside landscapes, but also for urban and peri-urban areas.

2.2. *Historic and Contemporary Design*

Researchers analyzing biophilic design have noticed that both professional and vernacular architecture of the past eras was biophilic in its qualities even if the term itself was not known [1,5,6]. According to E. L. M. Wolfs [6], architects and designers have been inspired by nature since antiquity. W Browning et al. [1] notice that animal themes could be found even in prehistoric-built structures and nature was used as a source of symbolic and decorative ornamentation and directly brought into exterior and interior spaces in the form of plants, animals, natural materials, etc. S. Keller et al., note that many organic features are often encountered in Gothic architecture and mention the Gothic Revival Harkness Tower at Yale University, designed by James Gamble Rogers as example of biophilic architecture [7]. According to A. Salingaros [5], this human–nature relationship remains important from traditional cultures until today, but has increasingly been abandoned with the rise of industrialization.

2.3. Natural and Artificial

According to N. Salingaros [5], the positive effects of biophilic environments are induced either by proximity and visual contact with nature (plants, animals, scenic views, natural materials, or even other people) or by artificial environments that "follow geometrical rules for the structure of organisms". For example, proximity with nature is visible in the designs using vegetated surfaces, as in the case of botanists Patrick Blanc's green walls [8]. An example of an artificial biophilic environment is the interior design by Adolfsson & Partners in the King office complex in Stockholm providing artificial forest experience for its employees [12]. In other words—it is possible to design artificial shapes and spaces that stimulate the same responses as natural environments and biological forms. In the first case the positive effect of biophilic design can be defined as the "healing influence of nature" and the second case is identified as "biophilic geometry" by N. Salingaros [5]. Similar approach is visible in nature in the space and nature of the space categories in the 14 patterns of biophilic design [1]. The better results would be obtained if both the healing influence of nature and biophilic geometry were be integrated into the project.

2.4. Explicit and Implicit Representation of Nature

N. Salingaros [5] distinguishes explicit and implicit representations of nature. Explicit representations of nature include direct visual representations of natural forms in design. The foliated sculpture by Kent Bloomer in the Ronald Reagan National Washington Airport terminal is an example [7]. Implicit representations of nature would be "organized complexity—purposeful complication that is also accompanied by a high degree of organization". This abstract characteristic of natural world can be achieved in artificial environments in numerous ways, creating hierarchies similar to natural ones and providing an information-rich expedience as an intriguing balance between boring and overwhelming [1]. An example of a multilevel organized light and space complexity is Genzyme Center interior space designed by Behnisch Architekten in Cambridge, Massachusetts [13]. Similar categorizing could be inferred from the 14 patterns of biophilic design, where "biomorphic forms and patterns" and "complexity and order" are distinguished as "natural analogues" [1].

3. Proposed Classification of Biophilic Architecture

The above-presented analysis of existing classifications applicable to biophilic architecture has revealed the lack of universal classification that would be suitable both to innovative and traditional buildings or to buildings based on the biophilic geometry and the healing influence of nature, or which integrate both of those aspects. Moreover, it would be desirable that the classification would reflect the interconnections between the architectural form of building and its biophilic properties. In order to develop such a classification, the analysis of existing biophilic design classifications presented in Section 2 was complemented with an additional review of the literature on the classification of architectural objects and features in the above-mentioned scientific literature databases as well as available Internet search engines and encyclopedias, the general overview of biophilic design principles [1,5,7,9], and existing examples of biophilic buildings. The search and general overview of biophilic architecture examples was carried out using available Internet search engines and keyword combinations such as "biophilic architecture", "biophilic building", "biophilic design", etc. The criteria for selecting examples for analysis were that the buildings were referenced in prominent architectural online editions and corresponded to the criteria of biophilic design. Bearing in mind that buildings having biophilic qualities are not always explicitly identified as biophilic, an additional overview was carried out in architectural websites and databases, such as ArchDaily, Divisare, Dezeen, etc. The iconographic material (photographs, drawings, visualizations) and the descriptions of projects were overviewed in light of biophilic design criteria, presented by A. Salingaros [5], W. Browning et al. [1], and S. Kellert et al. [7]. The analysis revealed the diversity of scales, functions, and expressions of biophilic buildings. The examples demonstrate that biophilic qualities can be achieved using the internal and external layers of vegetation and natural materials to mimic forms of natural landscape or biological organisms by creating a complex organization of volumes and spaces characteristic to natural environments. The results of this general overview allowed parallels to be made between the interconnection between ornament and architecture and biophilic qualities and architecture. Bearing in mind this semblance, the literature on ornament in architecture was reviewed and the classification of architectural objects by A. Tikkanen [14], based on the character and integration of ornament, was viewed as having potential for adaptation to classifying biophilic buildings. A. Tikkanen [14] has distinguished three types of architecture: mimetic or imitative (symbolic ornaments imitating natural features, structural elements of preceding wooden structures etc.), applied (ornament, often without precise symbolic meaning, applied as a surface element for pure decorative purposes), and organic (ornamental effect of the inherent qualities of building materials). Such principle of classification—mimetic, applied, and organic—was modified and adapted to biophilic buildings (Figure 1).

3.1. Mimetic Biophilic Buildings

In the case of biophilic architecture, mimetic biophilic buildings are those that achieve biophilic qualities by using forms which "have certain definite meanings or symbolic significance" [14]. This can be either through botanical motifs, imitation or interpretation of traditional architectural forms, or interpretation of landscape features in the design of the building. For example, the New California Academy of Science Museum designed by Renzo Piano integrates the interpretation of the surrounding hills in its roof structure [6]. Some mimetic biophilic design features can also be identified in the structures designed by Arata Isozaki and Zaha Hadid Architects (Figure 1).

3.2. Applied Biophilic Buildings

In the case of biophilic architecture, applied biophilic buildings are such designs, where biophilic qualities are added as a layer that appears extrinsic to the structure itself. These can be buildings with vertical internal and external greenery, interior parks, or roof gardens that, in addition to these biophilic features, maintain a modernist, high-tech, or sleek architectural outlook. The example of such approach is Khoo Teck Puat hospital in Singapore, which integrates modernist design and lush greenery and viable ecosystems and numerous other biophilic qualities [6], similar to Perez Art Museum, Miami, by Herzog & de Meuron (Figure 1). The applied approach is typical and successful in situations when biophilic refurbishment of the existing structure is necessary, as in the cases of Barbican estate in London.

3.3. Organic Biophilic Buildings

In the case of biophilic architecture, organic biophilic buildings are such designs where the synergistic relation between the biophilic qualities and the structure is achieved. In this case the biophilic qualities are inherent in a building's shape and arrangement of spaces, materials, and functions. The creative works of Barry Wark [15], like the Glasgow School of Art Extension, can be mentioned as the attempts to create a biophilic architectural form which would be capable of generating human health and well-being benefits without directly emulating elements of natural world and at the same time providing a habitat for other species, thus fostering a human–nature connection.

According to E. L. M. Wolfs [6], biophilic architecture holds unprecedented potential for bio-collaboration, where the integration of natural elements goes beyond aesthetics or symbolism. Organic biophilic design could potentially create environments of distinctive architectural expression that positively affect human health and well-being and provide a habitat for a variety of natural systems, which in turn can "provide wide-ranging services that are integral to solving today's major ecological concerns" [6]. According to E. L. M. Wolfs [6] bio-collaboration in design could occur on aesthetic, functional, and structural levels. While functional and aesthetic bio-collaboration is widespread in biophilic architecture, the structural bio-collaboration, where "the design is primarily made by a living organism" [6] is still in the experimental stage and is referred to as bio-integrated design [16].

4. Evaluation of Selected Building Examples

4.1. Case Study Buildings Selection

In order to analyze in greater detail, the means of expression and design strategies of different categories of biophilic buildings, a sample of case study buildings were analyzed. It was decided that the examples to analyze would be located in the territory of Lithuania, as biophilic design is oftentimes associated with climate zones allowing lush exterior greenery. The Lithuanian climate, with clearly expressed seasons, requires different approaches for creating biophilic qualities, thus we decided to concentrate on the variety of design means and approaches available in such a climatic context. Moreover, biophilic design ideas are just taking the first steps in Lithuania and distinguishing these examples and analyzing them serves an important factor for the entrenchment of biophilic design culture in the Baltic Sea region. In order to select the examples for analysis, prominent Lithuanian architecture journals (both printed and online) aimed at both the professional community and the general public were reviewed, and the buildings were selected based on their correspondence to biophilic design criteria as presented by A. Salingaros [5], W. Browning et al. [1], S. Kellert et al. [7]. Additionally, the possibility to attribute the objects clearly to one of the three distinguished design categories: mimetic, applied, and organic was considered. Each of three categories was represented by one case study example.

The following examples were selected for analysis:

1. Example A—Kindergarten "Peledziukas" [17] (Figure 2); Type of biophilic design: mimetic; Design: "DO Architects" (G. T. Gylyte, D. Baltrunas, K. Ciplyte, V. Babij, S. Daugeliene, A. Baldisiute, A. Neniskis, M. Vysniauskas); Location: Pagiriai, Vilnius; Year of completion: 2021. This object was selected due to its architectural expression (volume and materials) both modern and recalling traditional architectural design in the urban context. Moreover, this is a reconstructed building located in the urban context, where renovation and re-use as well as biophilic quality of the environment are of high importance.
2. Example B—Vilnius University Kairenai Botanical Garden's Green Building-Plant [18] (Figure 3); Type of biophilic design: applied; Design: Paleko "ARCH studija" (R. Palekas, B. Puzonas, D. Zakaite, A. Palekiene, V. Linge); Location: Kairenų st. 43, Vilnius; Year of completion: 2016. This object was selected due to its direct correspondence to the trend of applied biophilic design as this is reconstructed building, the biophilic character of which is created with vegetated columns—an unusual and experimental solution in Lithuanian climate conditions.
3. Example C—Recreation and Water Center in Zarasai (Figure 4) [19]; Type of biophilic design: organic; Design: Archartele ir partneriai (H. Staude and A. Minkauskas); Location: The island of the great Zarasas, Zarasai; Year of completion: 2015. This object was selected due to the synergetic effect between building's shape, materials, and environment creating a biophilic experience.

Figure 2. Kindergarten "Peledziukas" located in Vilnius, made with materials and roof configuration recalling traditional wood architecture was selected as an example of mimetic biophilic design. Photographs by A. Daugelaite.

Figure 3. Vilnius University Kairenai Botanical Garden's Green Building-Plant with external layer of vegetation was selected as an example of applied biophilic design. Photographs by A. Daugelaite.

Figure 4. Recreation and Water Center in Zarasai with landscape-inspired volumes and nature-like spatial characteristics was selected as an example of organic biophilic design. Photographs by A. Daugelaite.

4.2. Assessment of Case Study Buildings

The overall biophilic design aim, to restore broken human–nature connections, encourages an analysis of biophilic buildings not only from the point of their aesthetic expression and human well-being benefits, but also from the points of view of human–nature integration and human–nature collaboration. As it was mentioned in the previous section, aesthetic and functional bio-collaboration distinguished by E. L. M. Wolfs [6] is widespread in biophilic architecture. In this research we apply the more general term human–nature collaboration, used in the fields of sustainability aesthetics [20] and regenerative sustainability [21–23]. The term human–nature collaboration encompasses bio-collaboration in its turn but is not limited to it and includes such factors as designs' engagement with environmental forces.

In order to evaluate the mimetic, applied, and organic biophilic designs from the points of view of biophilic qualities, aesthetic expression, and human–nature collaboration a series of questions was formulated. It was first based on the biophilic design criteria [1,5,7] and other sources (Table 1) and then applied for on-site evaluation of three selected design examples, representing the above-distinguished trends.

Table 1. Questions used for the assessment of selected buildings as a means for design evaluation from sustainability aesthetics, biophilic design, and human–nature collaboration points of view [1,5,7,20–26]. Buildings correspondence to the criterion is evaluated in the scale from 0 to 2: None = 0 (gray color in the table); Some = 1 (yellow color in table); Clearly expressed = 2 (green color in the table).

Criteria of Architectural Expression		**Architectural Means/Explanation/Hint**	**Examples**		
			A	**B**	**C**
Features of environment	Does the object adapt to local terrain and landscape conditions?	Prioritize real nature over simulated nature; Adaptation to local terrain forms; Preservation of vegetation; Response to landscape character	2	2	2
	Does the object express the engagement with environmental forces (water, air, sunlight...) in meaningful and visible way?	Sun, shade, reflections; Integration of waterbodies; Rainwater management; Integration of vegetation; Possibilities to feel airflow, etc.	2	2	2
	Does the object integrate ecosystems and habitats in a meaningful and visible way?	Flora: ecological systems, visual continuity, trees, shrubs, vegetated ground covers, habitats, rare plant species, nectar rich vegetation, flowering wild local herbs etc. Fauna: birds, insects, land animals and reptiles, fish, endangered species, etc.; Bird box, bat box, biotope for specified insects	1	1	1
	Does the object provide opportunities for seeing, hearing or touching of water?	Naturally occurring: river, stream, ocean, pond, wetland; Visual access to rainfall and flows; Seasonal flows Simulated or constructed: water wall, constructed waterfall, aquarium, fountain, constructed stream; Reflections of water (real or simulated) on another surface; Imagery with water in the composition	0	2	2
Materials	Does the object integrate natural (and local) materials?	Real materials are preferred over synthetic; Materials and elements from nature that, through minimal processing, reflect the local ecology or geology to create a distinct sense of place, sometimes stimulating to the touch	2	2	2
Visual interest	Are there visual connections between the object and its environment present?	A view to elements of nature, living systems and natural processes; Prospect—an unimpeded view over a distance; Quality views from the outside and inside	2	2	2
	Does the object contribute to scenic quality or landscape character?	Architectural object interacts with landscape (identical, similar, contrasting) and forms qualitative wholeness	2	2	2
	Does the object provide views to elements of nature, living systems, and other living things at all?	Naturally occurring: natural flow of a body of water; Vegetation, including food bearing plants, animals, insects, fossils, terrain, soil, earth Simulated or constructed: mechanical flow of a body of water; Koi pond, aquarium; Green wall; Artwork depicting nature scenes; Video depicting nature scenes; Highly transformed, designed landscapes	2	2	2
	Does the object correspond to other unique physical features?	Unique site elements are integrated into the design	2	2	2
	Is the object harmoniously integrated in landscape/cityscape and looks visually balanced?	Part/whole relationships that may include balance, coherence, concinnity, consonance, orchestration, proportion, symmetry, symphony, unity	2	2	2

Table 1. *Cont.*

	Criteria of Architectural Expression	Architectural Means/Explanation/Hint	Examples		
			A	**B**	**C**
Shapes and forms	Does the object's design integrate / interpret natural forms and motifs?	Symbolic references to contoured, patterned, textured or numerical arrangements that persist in nature; Presence of natural (botanical, animal) motifs in the design	1	1	2
	Does the object's design mimic nature's forms (e.g., biomorphic shapes) in a functional way?	Functional biomimicry	0	0	2
	Is the object's design based on geomorphic shapes?	Relation to the form or surface features of the earth or landscape	0	0	2
	Does the object include spatial hierarchy similar to those encountered in nature?	Complexity that simultaneously stimulates senses of intrigue and order, and reduces stress	0	1	2
Light and space	Does the object integrate/provide natural light?	Architectural object provides users with natural lighting options	2	2	2
	Are light quality variations, such as diffused, filtered light, light and shadow, reflections present in the object?	Varying intensities of light and shadow that change over time to create conditions that occur in nature Naturally occurring: daylight from multiple angles, direct sunlight, diurnal and seasonal light, firelight, moonlight and star light, bioluminescence Simulated or constructed: multiple low glare electric light sources, illuminance, light distribution, ambient diffuse lighting on walls and ceiling, day light preserving window treatments, task and personal lighting; accent lighting Personal user dimming controls; Circadian color reference	1	2	1
	Is the spatial diversity, variability and interest integrated in the object?	Curving edges; Dramatic shade and shadows; Winding paths; Partially revealed spaces; Translucent materials; Obscuring of the boundaries and a portion of the focal subject	2	1	2
Processes/Patterns *	Does the object create sensitive and cognitive variability and/or richness?	Information-richness, balance between boring and overwhelming	2	2	2
	Does the object express the process of co-creation with nature?	Construction using mycelium, technologies with algae for energy production and air quality improvement, "bio-concrete" made of moss and beef mushrooms in rainwater and allowing plants to be grown on the facades, salt slabs made of salt, sunflower and algae, bioplastics made of algae, etc.	1	2	1
	Does the object express the structural patterns related with fractality, centrality, part-whole integration?	Self-similarity across different scales. Integration or interpretation of naturally occurring fractals: branches of trees, animal circulatory systems, snowflakes, lightning and electricity, plants and leaves, geographic terrain and river systems, clouds, crystals; Nested fractal designs Action of a central element in its periphery Part-whole integration—relation of object's parts to the whole object itself; Application of the Fibonacci series, the Golden Mean	1	1	1
	Does the object express in a meaningful and visible way the behavior patterns characteristic to natural systems and organisms?	Change over time; Decaying—changing properties (rusting metal, wood changing color over time), natural patina of materials (leather, stone, copper, bronze, wood); Growing plants, moss	2	2	2
	Does the object express the stochastic and ephemeral connections with nature?	Integration, emphasis of naturally occurring phenomena: cloud movement, breezes, plant life rustling, water babbling, insect and animal movement, birds chirping, fragrant flowers, trees and herbs. Simulated or constructed: billowy fabric or screen, materials that move or glisten with light or breezes, reflections of water on a surface, shadows or dappled light that change with movement or time, nature sounds broadcasted at unpredictable intervals, mechanically released plant oils	1	2	1
	Does the object provide thermal and airflow variability?	Naturally occurring: solar heat gain, shadow and shade, radiant surface materials, space/place orientation, vegetation with seasonal densification Simulated or constructed: HVAC delivery strategy, systems controls, window glazing and window treatment, window operability and cross ventilation	2	2	2

Table 1. *Cont.*

	Criteria of Architectural Expression	Architectural Means/Explanation/Hint	Examples A	Examples B	Examples C
Human–environment relations	Does the object maintain/contribute to the spirit of place?	The design maintains/contributes to tangible (buildings, sites, landscapes, routes, objects) and the intangible elements (memories, narratives, written documents, rituals, festivals, traditional knowledge, values, textures, colors, odors, etc.) of the spirit of place. The object connects to the essence of the place in ecological, cultural, historic, geographic dimensions	2	2	2
	Does the object involve restoration of the damaged environment in meaningful and visible way?	Improved ecological situation: surfaces are permeable to water, variety of vegetation, rainwater management (bioswales, raingardens, etc.), a section of the courtyard is left for natural succession (that is, to naturally grow and regenerate), composting biodegradable waste; Design prioritizes biodiversity over acreage, area or quantity	0	2	0
	Does the object employ/demonstrate self-healing qualities of nature?	Little maintenance is required, the site is self-operating like in natural places, like meadow or forest	0	0	0
	Does the object stimulate exploration and cognition?	The object creates the conditions that differentiate between surprise (i.e., fear) and pleasure, creates a sense of mystery, risk/peril, arouse interest of exploring Mystery created by the promise of more information achieved through partially obscured views or other sensory devices that entice the individual to travel deeper into the environment. e.g. Peek-a-boo windows that partially reveal, curving edges, winding paths. Risk/Peril is created as an identifiable threat coupled with a reliable safeguard: double-height atrium with balcony or catwalk, architectural cantilevers, infinity edges, façade with floor-to-ceiling transparency, experiences or objects that are perceived to be defying or testing gravity, transparent railing or floor plane, passing under, over or through water, proximity to an active honeybee apiary or predatory animals, life-sized photography of spiders or snakes	2	1	2
	Does the object stimulate sense of security in users and viewers perception?	Creating physical and mental safety, refuge—a place for withdrawal, from environmental conditions or the main flow of activity, in which the individual is protected from behind and overhead	2	2	2
	Does the object stimulate sense of attraction and emotional, spiritual connection with it and its place in users and viewers perception?	People are taking photographs, collect litter, spend their free time in and around the object	2	2	2
	Does the object stimulate experience of nature through senses?	Design stimulates auditory, haptic, olfactory, or gustatory stimuli referring to nature, living systems or natural processes. Naturally occurring: fragrant herbs and flowers, songbirds, flowing water, weather (rain, wind, hail), natural ventilation (operable windows, breezeways), textured materials (stone, wood), crackling fire/fireplace, sun patches, warm/cool surfaces Simulated or constructed: digital simulations of nature sounds, mechanically released natural plant oils, highly textured fabrics/textiles that mimic natural material textures, audible and/or physically accessible water feature, music with fractal qualities, horticulture/gardening, including edible plants, domesticated animals/pets, honeybee apiary	1	1	1
	Does the object stimulate connection with natural systems?	Naturally occurring: climate and weather patterns (rain, hail, snow, wind, clouds, fog, thunder, lightning), hydrology (precipitation, surface water flows and resources, flooding, drought, seasonal flows), geology (visible fault lines and fossils, erosion, shifting dunes), animal behaviors (predation, feeding, foraging, mating, habitation, migration), pollination, growth, aging and decomposition (insects, flowering, plants), diurnal patterns (light color and intensity, shadow casting, plant receptivity, animal behavior, tidal changes), night sky (stars, constellations, the Milky Way) and cycles (moon stages, eclipses, planetary alignments, astronomical events), seasonal patterns (freeze-thaw, light intensity and color, plant cycles, animal migration, ambient scents) Simulated or constructed: simulated daylighting systems that transition with diurnal cycles, constructed wildlife habitats (e.g., birdhouse, honeybee apiary, hedges, flowering vegetation), exposure of water infrastructure	1	2	2
		Total:	42	49	52

* Pattern—a form or model proposed for imitation.

31 questions subdivided into 7 categories—features of environment, materials, visual interest, shapes and forms, light and space, processes/patterns, and human–environment relations—were answered evaluating the answer in the scale from 0 to 2, evaluation 0 meaning that qualities are not present and 2 meaning qualities are clearly expressed. The highest

possible evaluation of the building using this approach is 62. Quantitative assessment of case study buildings has revealed that all of them can be considered as biophilic buildings, having features of sustainability aesthetics and human–nature collaboration as the evaluation score in all three cases has exceeded 30. Object A—Kindergarten "Peledziukas" was evaluated with the score 42, the lowest of all three case study objects with weakest evaluation in the categories of human–environment relations and shapes and forms. Object B—Vilnius University Kairenai Botanical Garden's Green Building-Plant was evaluated with the score 49 with weakest evaluations in shapes and forms category. The lower evaluation of shapes and forms of both buildings is determined by the fact that both objects are reconstructed Soviet era buildings. The facts of reconstruction and adaptive re-use give positive consideration from sustainability point of view. Object C—Recreation and Water Center in Zarasai received 52 scores from 62 and demonstrates the highest presence of biophilic qualities from all the evaluated case study objects. The weakest evaluation of this object is in the category of human–environment relations as well as in the first case study building. It is possible to conclude that the potential possibilities provided by restorative and regenerative approaches to design were not employed in these projects.

4.3. Descriptive Analysis and Discussion of Case Study Buildings

Descriptive qualitative analysis of case study objects provides the example of analyzing and discussing the buildings and their surroundings from biophilic design, sustainability aesthetics, and human–nature collaboration points of view offering a different angle for looking at projects and their implementation. The descriptive analysis of each object was elaborated based on the questions presented in the Table 1, demonstrating the suitability of this approach for both quantitative and qualitative analysis of buildings.

Kindergarten "Peledziukas". The object's terrain is flat, and the object is placed there without extreme changes in the terrain. The object is strongly engaged with the sun—it provides many opportunities of feeling the sun in different angles and places and provides shaded areas under the trees or tracery walls. The vertical timber panels cast changing shadows. The object provides a lot of open spaces, such as the inner garden, a rooftop terrace, playgrounds, etc. with a possibility to feel the air. However, there are no water features.

The project deserves the highest evaluation of the efforts to preserve the trees (the initial idea of the project was changed in order to save the old spruce tree, which even has a tale of origin). However, the area is poor with other parts of ecosystem, such as fauna habitats or wild herbaceous flowering plants. There is not any water element. The object is constructed of timber, which dominates in the interior and exterior and furniture design.

The object provides very strong visual connections among its spaces (for example, children can see the work at the canteen or cleaner's room) and to the outside with views to the pine grove from the roof terrace, which obviously add value to the project. The object definitely contributes to scenic quality of the area.

The object looks visually balanced and well placed. Strict lines and forms dominate in the building, which is rarely found in nature. Biomorphic forms are not directly visible in the design; aside from the color and shape of the roofing which recalls traditional wooden architecture as well as the stylized owl's ears that can be associated with the owl-themed name of the institution (Pelėdžiukas translates to owlet in English). The site's surface is flat, thus it is not applicable to the evaluation of geomorphic forms. Spatial hierarchy is expressed in the building's volume, but the object lacks fractality.

The object provides sunlight from different angles and in different daytimes, however lighting variations (interplay of light and shadow, diffused light, etc.) are rare. The object is rich with diverse and partially revealed spaces and their dynamics and creates cognitive variability. A co-creation with nature is expressed through the naturally aging wood cladding.

The object has strong relation between the whole and its parts. The centrality of the object is created through the central garden which forms the core of the whole project. Ephemeral connections with nature may be felt by seeing naturally occurring phenomena through the windows (like cloud movement, birds, etc.). There is a lack of other senses, like smells of plants, blooming flowers, water features or animals, insects, etc. life. The curtains in the corridor may rustle with light breeze. The windows are openable and the rooms can be ventilated, and air movement can be felt.

The object contributes to the spirit of place by enriching it with innovative architecture and improving the urban landscape of the area. Although the existing trees are involved beautifully in the design, other features of improving the local ecology, such as permeable surfaces, variety of vegetation, biodiversity, etc. are missing.

The object definitely stimulates exploration and cognition by involving "mystery" elements in partially revealed spaces, roof terrace, and walls with floor-to-ceiling transparency. The sense of safety and attraction is strong. The experience of nature and connection to the living systems could be stimulated through the senses even stronger. It is possible to feel warm/cool surface in sun-shaded areas, natural ventilation in the building, or feel the breeze while being in the courtyard, as well as see weather conditions through the large windows or touch the natural wood on the facade. However, auditory, olfactory, or gustatory stimuli are not reflected and the project could be enriched with flora and fauna.

Vilnius University Kairenai Botanical Garden's Green Building-Plant. The object's terrain is flat. The object is placed there without extreme changes in the terrain. The building engages with environmental forces by the vegetated façade that provides light and shadow interplay, the sound of wind through the plants, a little fountain is integrated near the entrance of the building, and large pond is located on the site. The object integration with local ecosystems and habitats is not visible despite the fact that it is located in the botanical garden. The project contains few habitats for the fauna in the backyard, there are shrubs growing on the premises to the building, however, in terms of habitat it is probably insufficient. Flowering plants for bees or butterflies are found further from the building premises. Concrete paving is hardly permeable surface, however, it only takes up a small area. The object provides views to the pond and fountain and it is possible to hear and touch the water on the building's site.

The object's façade is constructed of planted columns which encourages interest and desire to touch. The columns are constructed of local turf. The building is a reconstructed Soviet era apartment building. The views to the living systems and natural processes are obvious. The building provides an unimpeded view over a distance, views from the building are exceptional. The building definitely supplements the landscape. A unique site characteristic is the botanical motif which is transferred to the building. The building looks visually balanced itself and on the site.

Strict lines and forms dominate in the building, which is rarely found in nature. However, the planted columns soften the impression. The site's surface is flat, thus it is not applicable for the evaluation of geomorphic forms. Spatial hierarchy is not expressed and the main façade elements are of one size. The exception is the front garden which is a labyrinth that provides the full scale of fractals.

The spatial diversity, variability, and interest is high. The interplay of light and shadow is variable, however, these features could be expressed even stronger by more expressive loops of the paths and partially revealed spaces in the interior, etc. The process of co-creation with nature is strongly expressed. The object forms a strong relation of its parts to the whole object itself and event to its site which includes reference to fractal systems (planted surfaces), and provides the possibility to feel the airflow and hear nature sounds through open windows, feel the natural smells while being on the site, see water reflections, cloud movement, fountain water babbling, etc.

The object connects to the essence of the place by adding value to its character. Landscape restoration is not included and the surrounding lawn is poor in biodiversity terms. The project definitely improved the existing ecological situation. However, there is little information of how the rainwater is treated and if, for example, a section near the pond is left for natural succession (that is, to naturally grow and regenerate). These means could help to improve the richness of biodiversity. The site requires constant maintenance and self-healing qualities are not visible.

The object raises interest; however the stimulation of exploration and cognition may be expressed stronger by risk/peril and mystery means. A sense of security is strong. A conscious attempt to include auditory, haptic, olfactory, or gustatory stimuli into the design is not visible, however, some of these emerge from the special site itself. A connection to natural systems is stimulated through feeling (on the site) and observing (through windows) of naturally occurring processes like climate and weather, seasonal and diurnal patterns, and the feeling of the presence of vegetation and water. However, life of fauna is little expressed due to lack of wildlife habitats (e.g., birdhouse, honeybee apiary; hedges, flowering vegetation).

Recreation and Water Center in Zarasai. The object nicely integrates man-made structure and natural landscape. The architectural structure connects land and water. The question may arise about whether it is a building, a bridge, or a path. Structural variety offers possibilities to touch the water or to feel the wind breeze, shade, and sun. Although ecological systems such as habitats, rare plant species, nectar rich local vegetation, and others are not integrated in the project on purpose, it offers visual continuity of a man–nature made landscape, and opportunities to find fauna life in the trees or the lake.

Timber cladding reflects the local materials. Visual connections between the object and its environment are strong from both the inside and outside. The object definitely contributes to the scenic quality. The object provides views to elements of nature and living systems including the lake. The object provides the paths over water and roof terraces. The object takes advantage of the unique lake shores and existing tree line. The object looks harmoniously integrated in the landscape.

The object's design is based on an organic, naturally flowing form that looks like it is grown out of its site. Biomorphic shapes are repeated through the object's design—rooms or roof terraces are evolving out of the paths, etc. The object creates geomorphic forms and the image of the hills rising up or down. This feature expressed the spatial hierarchy as well. The object provides light from different angles and offers some dramatic shadows, however, light variations are not very rich. Curving edges and winding paths partially revealed spaces to offer spatial variability.

The object is information-rich and involves the process of co-creation with nature through decaying natural wood and strong connections with landscape. Fractality is not expressed. The object creates a central focal point of interest in the landscape and part-whole integration is nicely expressed. The object has a wonderful location; however, it expresses the stochastic and ephemeral connections with nature only partially. It could integrate more strongly the life of birds, insects, wild plants, and others, however, its impermeable asphalt surfaces, shortly cut lawn, and lack of surrounding biodiversity show the lack of landscape restoration means in a meaningful and visible way. It could be done additionally without changing the properties of the object itself. Thermal and airflow variability is rich and is provided by the possibilities of the variety of spaces. The object contributes to the spirit of place by enriching the landscape and providing strong attraction, as well as a meeting and recreational point in a small town. The site requires maintenance, although it would require less if the meadows would be left to bloom.

The object stimulates exploration and cognition by creating a sense of mystery, risk/peril and arouses the interest of exploring. Winding paths, terraces, and paths over water invite a visitor for a stroll. The sense of safety is strong as well as attachment to the area. As the object may be visited at night, it offers experiences of stargazing, watching the moon, etc. However, auditory, olfactory, or gustatory stimuli are not reflected and the project could be enriched with flora and fauna, especially those natural to its wild location.

It is possible to conclude that all three analyzed projects are strong at integrating environmental features, however struggling with the inclusion of fauna life, such as insects, and flora, like blooming local flowers. Biodiversity on the sites is not rich enough and surfaces are rarely permeable. Therefore, it leads to difficulties for implementing the design criteria of engagement to living things and other sensorial stimuli like smells. This confirms the results of quantitative evaluation, demonstrating the lack of human–nature collaboration and restorative and regenerative approaches in case study objects. Although projects are strong in creating good pieces of architecture, they could have more features to provide senses of mystery, risk/peril, and naturalness, as well as spaces requiring low maintenance and offering a variety of natural processes that enrich people's lives. However, all three case study objects confirm that it is possible to create biophilic buildings and biophilic interior and exterior experiences in the Lithuanian climate not only in natural, but in urban environments as well. Moreover, biophilic qualities were successfully created even in the cases of Soviet era buildings reconstruction and adaptive re-use.

5. Conclusions

The significance of the biophilia hypothesis and biophilic design in providing favorable conditions for human well-being and healthy development in anthropogenic environments, restoring human–nature connections, and potentially bringing the development of built environments and human habitats to human–nature collaboration level significant for regenerative sustainability encourages the analysis of possibilities of architectural expression of biophilic buildings.

Existing classifications of biophilic design distinguish such trends as inspired by nature and traditional biophilic design, historic and contemporary biophilic design, natural and artificial biophilic design solutions, and explicit and implicit representation of nature in biophilic design. Analysis of the literature has revealed the lack of a universal biophilic design trends classification that would be suitable both to innovative and traditional buildings or buildings based on the biophilic geometry and on the healing influence of nature or integrating both of those aspects.

The classification reflecting the interconnections between the architectural form of a building and its biophilic properties was developed in the course of this research. Biophilic buildings are categorized into mimetic, applied, and organic: mimetic biophilic design achieves biophilic qualities by using symbolic, mimetic forms related to nature or traditional architecture; in the case of applied biophilic designs biophilic qualities are added as a layer, which appears extrinsic to the structure itself; in case of organic biophilic design a synergistic relation between the biophilic qualities and the structure is achieved. The analysis of bio-collaboration and the human–nature collaboration potential of these trends has revealed that all three trends hold the potential in these fields with particular attention to organic design and its structural bio-collaboration possibilities. Evaluation of three selected building examples located in Lithuania corresponding to mimetic, applied, and organic trends according to a comprehensive set of biophilic design criteria confirmed the highest potential for the organic trend to create biophilic environments and the suitability of the applied trend for successful biophilic reconstruction of existing buildings. However, it is possible to conclude that application of each of these trends allows for the creation of biophilic buildings and biophilic experiences in different climatic conditions including in the temperate climate zone.

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