To what extent is biophilia implemented in the built environment to improve health and wellbeing? – State of the Arts Review and a Holistic Biophilic Design Framework

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Abstract:

As human beings have detached themselves from natural environments by spending most of their time indoors, they have also distanced themselves from the positive experiences that nature provides. Sick building syndrome, nature deficit disorder amongst others, are examples of the impact of separating the built environment from nature. Biophilia is an innate affiliation to nature which stems from our evolutionary history, vital for sustaining health and wellbeing. Biophilic concepts have been explored from biophilic cities to biophilic hospitals. However, existing biophilic research are fragmented. In the last few decades, energy efficiency and carbon emissions have increased in importance for low environmental impact design, nonetheless there is a need for more research in biophilic buildings which are beneficial to our health and wellbeing as well as causing less harm to the environment. This paper aims to investigate the application of biophilia in building design practices for improved health and wellbeing. Firstly, biophilic theoretical frameworks developed by leading biophilic experts have been examined and compared to health and wellness performance certifications such as WELL Building and Living Building Challenge (LBC) standards. Finally, a holistic biophilic framework inspired by Kellert and Calabrese, has been elaborated to assess the biophilic features in the built environment. Multiple explorative case studies were employed for this paper, the findings revealed that the biophilic applications linked to direct experiences of nature were implemented inefficiently and lacked a holistic approach to improve health and wellbeing. The authors argue that biophilia needs to be included holistically to maximise the benefits of nature's experiences.

1 Introduction

Humans once lived in small communities, held small farms and acknowledged the dependencies on nature, aware of the importance of its cycles, seasons and weather for survival. Today, 55% of the world's population now resides in urban areas and is predicted to rise to 68% by 2050. (UN Department of Economic and

Social Affairs 2018). People spend up to 90% of their time indoors, (BREEAM 2018a, p. 2) and a further 6% in an enclosed vehicle (Klepeis et al. 2001). Not only are humans the dominant species on earth but they are also distancing themselves from nature while corrupting the environment, but most importantly, impact the future generations ability to survive. Humans have become an indoor species which favours artificial environments over natural ones.

Nature provides food, shelter, soil, water and air, vital to our survival, yet human beings are destroying these fundamental elements on a profound scale. Humans have altered the planet's physical, chemical and biological features on a geological level. As urban environments have become the daily setting for many, energy is primarily consumed in buildings and accounts for 40% of all energy use, and responsible for 36% of all CO_2 emissions. (European Commission 2018). Energy saved by design such as bioclimatic design and energy modelling, have improved buildings with considerable reductions in energy use, before adding photovoltaics, geothermal or wind. Although energy efficiency is a necessary move for buildings which cause less harm to the environment, they also need to consider the health and wellbeing of occupants.

In the last few decades, biophilia has been implemented to improve health and wellbeing, a technique which brings vegetation into cities, streets, and interiors. Biophilia is described as a preference for natural environments, as we have evolved for 99% of our species evolution outdoors, the human brain requires natural stimulations. As buildings are around for decades and urban environments the daily setting for many, building design should promote health and wellbeing through interactions with nature. Urban environments are generally described as unhealthy which is reflected in the green building ratings standards, such as BREEAM and LEED who have acknowledged the importance of implementing health and wellbeing measures.

This paper considers the field of biophilia, which has matured and broadened with a range of theoretical and conceptual frameworks, this will form the foundation for a holistic biophilic framework. The paper aims to identify the extent biophilia is implemented for improving health and wellbeing in the built environment.

1.1 Significance

Biophilia is "the urge to affiliate with other forms of life" (Wilson 1984, p.85). In the last few decades biophilic design has received increased attention and significance in the built environment and is being implemented to improve health and wellbeing. Empirical studies confirm that biophilia improves concentration,

decreases fatigue, improves mental wellbeing through the visual connections to nature. (Kaplan. R. & Kaplan. S. 1989). According to Louv (2008), the absence of nature has contributed to decreased health and wellbeing and may be linked to increased obesity, depression, and attention disorders in children.

As a new biophilic framework to assess the experiences of nature is required to address the inadequacies in the built environment. (Kellert et al 2008; Browning et al 2014, Xing et al 2017; 2018). Key concepts and theoretical backgrounds from the literature were employed to support the biophilia hypothesis. The research heavily relies on the practice of biophilia by Kellert and Calabrese for the design of a holistic biophilic framework.

1.2 Methodology outline

A qualitative research design was employed for this paper, to understand a contemporary phenomenon, such as how biophilia is implemented in recently completed projects and why. Multiple case studies were selected to assess biophilic features, guided by the holistic biophilic framework. Four case studies were assessed for their biophilic applications, selected from the RIBA awards, however, these are anonymised. Content analysis was used for the data collection, several sources and formats were employed:

- Project descriptions from the architect's websites
- RIBA website descriptions
- Observations from videos and images

The case studies were evaluated by building designers who have knowledge of biophilia and its applications. To evaluate the biophilic applications, case studies were analysed individually and collectively to look for trends and patterns, with results represented categorically through tables. Tables captured and summarised the findings for examination of similarities and differences.

2 A State-of-the-Art Review – existing GBRT / health and wellness performance-based standards and the biophilia hypothesis

2.1 The biophilia hypothesis and multisensorial experiences provided by nature

The term biophilia was initially devised by social psychologist Erich Fromm, who broadly defined it as "the passionate love of life and of all that is alive" (1973 pp. 365-366). Subsequently defined further and popularised by American biologist

Edward O. Wilson, in his book Biophilia (1984, p. 85) as “the urge to affiliate with other forms of life”. Furthermore, biophilia stems from the evolutionary history of the human species and is still vital to people’s health and wellbeing in modern society, (Wilson 1986; Kellert and Wilson 1993; Kellert 1997; 2012). For 99% of our species history, humans developed to adapt in response to natural environments, there is a mismatch, the brains of early humans developed in different environments to today’s. Kellert and Calabrese (2015, p. 3) argues that “The human body, mind, and senses evolved in a bio-centric not a human engineered or invented world.” Humans left rural areas to reside in cities, which grew in numbers and size, people favour artificial environments over natural ones, with irreversible impact on the planet. Nonetheless Wilson (1993, pp. 31-41) explains that biophilia hasn’t disappeared since the migration to cities and continues to play a vital role in the built environment. Kellert’s work will be assessed further along with frameworks elaborated by experts in the field of biophilia. Biophilia is a much-needed innate affiliation to nature which we have distanced ourselves from.

Biophilia is a multisensorial experience, our physiognomy is designed to respond to natural environments. Non-dynamic environments shut down our senses, and lose contact with the world, our brains desire the variances, sounds, movements and scents provided by nature. Architects and scientists understand the importance space and place have psychologically and physically. However, previous studies have almost exclusively focused on the beneficial effects of visual connections to nature compared to all other senses, such as olfactory and acoustic.

The artificial settings imposed on individuals in modern society is mostly sensory deprived. Too often, buildings are bland environments, deprived of sensorial stimulation, resulting in places where fatigue and boredom sets in. This has a negative impact on our psychological and physical wellbeing. Unfortunately, nature in the built environment is largely treated as a problem or an irrelevant matter, resulting in decreased interaction between people and nature. Additionally, sensory deprivation is distressing for the brain, decreasing its plasticity, the same thing all day long is harmful to our health and wellbeing. (Behling 2016). Furthermore, mood is defined and affected by what we do, see, hear and smell in that space (Steinberg 2015). Extended exposure to nature in healthcare facilities which implemented biophilia resulted in improved recovery rates, less pain relief administered, lower blood pressure, along with improved working conditions for staff. (Ulrich 1993; 2008, Kellert and Heerwagen 2007; Townsend and Weerasuriya 2010; Wells and Rollings 2012; Louv 2012; Marcus and Sachs 2014). The biophilia hypothesis supported by vast amounts of empirical studies, confirms that contact to natural environments offers a potent aesthetic stimulus.

Direct contact with nature has the most profound impact on health and wellbeing, decreased stress, improved cognitive performance, along with improved mood and emotions.

Noise, unpleasant odours, artificial light and air conditioning cause stress, making us sick, healthcare facilities and hospitals are rarely associated with improved comfort, health and wellbeing. Multisensorial encounters with the natural environment should be encouraged by incorporating indirect and direct contact with nature. This would promote sensorial stimulation and provide humans the much-needed exposure to nature to improve health and wellbeing. British Research Establishment (BRE) is also taking an active role on the impact the built environment has on health and wellbeing, Flavie Lowres, Associate Director of BRE states that "energy efficiency is now imbedded in the construction thinking and processes…the focus is shifting more and more towards the health and wellbeing of the building occupants". (BRE 2018, p. 1). Biophilia is the missing link for true sustainability. (BRE 2018, Xue et al 2019).

2.2 Green building rating standards

Green building standards such as BREEAM's (Building Research Establishment Environmental Assessment Method, by BRE) new construction standard for non-domestic buildings includes a category on health and wellbeing and accounts for 14% of the total credits. Credits are given for the provision of outdoor spaces, landscaped areas and biophilia to provide building users with direct experiences of nature. Daylighting and views onto nature, along with passive strategies are included. (BREEAM 2018b, pp.72-126). However, a recent study by Xue et al (2019) argues that green building rating tools (GBRT) should shift from the energy-oriented approach to a human centred one through a biophilic framework. Furthermore, health and wellness performance-based certification programs include biophilic design guidelines for improved health and wellbeing within topics such as air, water, nourishment, fitness, comfort and mind. However, a study by Obrecht (2019, p. 5) explains that many of the topics in GBRT and Health and Wellness performance-based standards relate to building management and services rather than the design of buildings. The importance of health and wellbeing were acknowledged in several government policies, green building standards and certification systems. For example, the UK National Planning Policy framework aims "to enable and support healthy lifestyles, especially where this would address identified local health and well-being needs" (Ministry of Housing, Local Communities and Local Governments 2018, p.27). There is a lack of emphasis on health and wellbeing in green building design tools.

Certification schemes	Environmental category/imperative	Assessment Criteria
WELL Building Standard 2018 V2	M02 Access to nature M07 Restorative spaces M09 Enhanced access to nature	Provide access to nature Nature incorporation Culture, place, flora, art, delight
LBC Living Building Challenge 2019 V4	11 Access to nature 19 Beauty & Biophilia	Interior/exterior connection to nature Connect to place, climate, culture and community

Table 1: Summary of biophilic measures in Well and LBC

Different from energy oriented GBRTs, there are two health and wellness performance-based certification schemes: WELL Building and Living Building Challenge (LBC) standards. The WELL Building standard is developed by the International WELL Building Institute, (IWBE), WELL measures elements associated to building design that affects occupant health and wellbeing. Air, water, nourishment, light, movement, thermal comfort, sound, materials, mind and community, all topics are backed up by medical and scientific research. The Living Building Challenge (LBC) is developed by the International Living Future Institute, with several levels of certification, which measures building design elements related to place, water, energy, health & happiness, materials, equity and beauty.

Both schemes assimilated the application of biophilic design. As summarised in Table 1. Both WELL and LBC have included direct connections to nature such as access to nature, incorporation of nature, connection to place, culture and community. Both WELL and LBC prescribed outdoor biophilia and indoor biophilia for improving health and wellbeing, addressed direct connection to nature through natural lighting, views onto nature.

However, WELL is comprised of preconditions (which are required) and optimisations (which are recommended), M07 and M09 are within the optimisation category. In comparison to LBC, all imperatives are mandatory, furthermore LBC provides a biophilic design guidebook based around Kellert's six elements. Environmental features, Natural shapes and forms, Natural patterns and processes, Light and space along with Evolved human nature relationships. (Biophilic Design Guidebook, LBC, p. 11).

2.3 Biophilic design applications in the built environment and associated design frameworks

In the last few decades, biophilia has received increased attention in the built environment (Farr 2011; Beatley 2011), to provide humans with vital exposure to nature. Biophilic urbanism has obtained increased consideration in academia and practice. (Beatley 2011; Farr 2011; Beatley and Newman 2013). Biophiliccities.org founded by Tim Beatley aims to "advance the theory and practice planning for biophilic cities" (Beatley 2018 p. 1) and describes a holistic approach to biophilia to include the conservation of wildlife along with providing humans the much-needed sensorial stimulation. An exemplary biophilic city is Singapore. The city has implemented an abundance of natural features and although population has increased by 2 million over two decades the vegetation has increased from 36% to 47%. (Biophilic Cities 2018 p. 1). Park connectors allow people to walk, bike and jog between numerous areas of the city. Vegetation is used as a climate modifier, high rise buildings, hospitals and schools use green facades, roofs to decrease the urban heat island effect whilst purifying air. Singapore's Koo Teck Puat Hospital KTPH received the biophilic award (Green Pulse 2018 pp. 5-7). Climatic studies performed on the KTPH reveal temperatures were considerably lower in the afternoon due to shading from vegetation and evaporative cooling from water features (Green Pulse 2018 pp. 5-7). Biophilia when implemented correctly can provide multifunctional solutions to common design problems in the built environment.

As a holistic approach to biophilic design is required, the biophilic application along with the biophilic principles as defined by Kellert and Calabrese (2015), provides a suitable evaluation method for assessing biophilic features for improved health and wellbeing. According to Kellert and Calabrese (2015, p. 6) "Biophilic design seeks to create good habitat for people as a biological organism in the modern built environment that advances people's health, fitness and wellbeing". The following five fundamental principles of biophilic design were identified by Kellert & Calabrese (2015, pp. 6-7) as;

1. Biophilic design requires repeated and sustained engagement with nature;
2. Biophilic design focuses on human adaptations to the natural world that over evolutionary time have advanced people's health, fitness and wellbeing;
3. Biophilic design encourages an emotional attachment to settings and places;

4. Biophilic design promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities;
5. Biophilic design encourages mutual reinforcing, interconnected, and integrated architectural solutions.

However, those principles can only be followed by the successful implementation of biophilia through a framework. As discussed previously, this set of principles is currently not employed in any health and wellness standards or GBRT. Several biophilic design frameworks have been created. Terrapin Bright Green created a framework (as in Appendix A) which links biophilic features to health and wellbeing outcomes. Similarly, to Kellert and Calabrese's theoretical framework, Terrapin Bright Green's 14 biophilic patterns also distinguishes between nature in the place, nature analogues and nature of the space. This framework is partially based on Kellert's biophilic theories and includes three categories of implementation. Furthermore, each is linked to aspects of health and wellbeing such as: stress reduction, cognitive performance and emotion, mood & preference. The proposed framework could provide design strategies to address specific health and wellbeing outcomes for a range of environments. Finally, a conceptual framework focused on urban environments has been proposed by Beatley (Appendix B) who coined the term biophilic city and linked the biophilia hypothesis to urban planning, to incorporate economy and improved health and wellbeing of population, along with recovery of urban landscapes (2011). He developed a biophilic pathway to urban resilience, the framework compared to Kellert and Calabrese, is aimed at the macro scale with a less detailed approach to its application. Based on previous research (Kellert and Calabrease2015; Beatley 2011; Farr 2011; Beatley and Newman 2013), the authors have developed the following design framework which consists of three main experiences of nature and corresponding attributes, totalling to twenty-four biophilic features as in figure 1. The combination of the biophilic principles and application methods provides a complete framework for the evaluation or implementation of biophilia in the built environment.

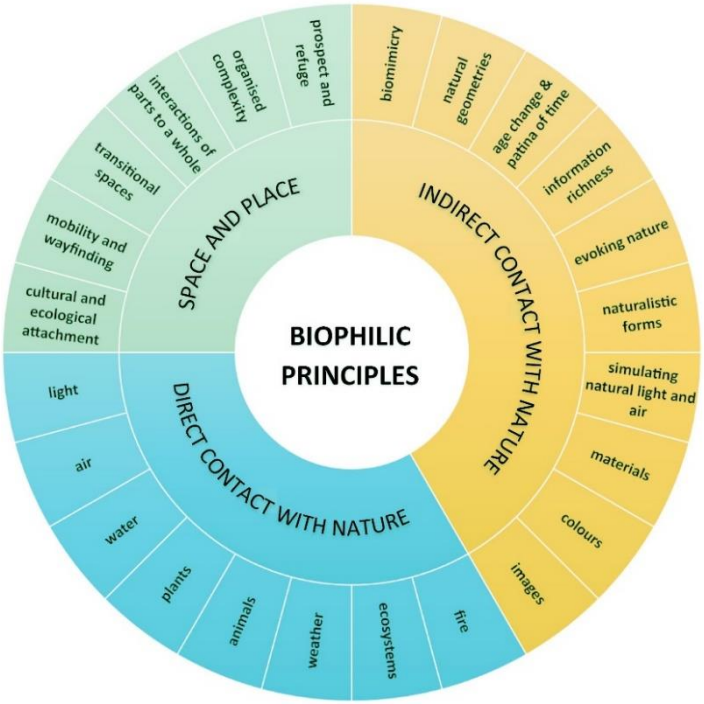


Figure 1: Biophilic Design Framework. Adapted from Kellert and Calabrese (2015, pp. 6-20)

2.4 Summary of the State-of-the-Art Review

It is observed that humans have distanced themselves from nature, spending most of our lives inside buildings and connecting with technology. The built environment has been linked to several illnesses and disorders, some more recognised that others: NDD and SBS, which further supports the idea that the lack of nature is affecting our health and wellbeing. Biophilia provides a holistic approach to sustainable design: conservation of natural environments; improved health and wellbeing; climate modification; energy efficiency. Its application has been defined by many researchers such as Kellert and Calabrese's theoretical frameworks and Terrapin Bright's 14 biophilic patterns. Furthermore, empirical evidence supports the beneficial impact of biophilia on health and wellbeing, both psychologically and physically. Specifically, direct contact to nature through the application of light, air, water, plants and ecological landscapes.

Although biophilic features are widely implemented in urban environments, there are few which have adopted a holistic approach to sustainable design, in most countries and cities biophilia is not considered as an important feature for promoting health and wellbeing. Typically, buildings lack direct contact to nature; green views, plants and natural daylight or access to green areas are not a priority. Hospitals, educational buildings, office buildings and homes and generally devoid of vegetation and natural elements, despite a growing body of knowledge proving the beneficial impacts of experiences of nature on health and wellbeing. All main sustainability assessment standards such as BREEAM, WELL and LBC include natural ventilation, thermal comfort, lighting and ecological features, but lack the holistic approach to biophilia as defined by Kellert and others. Specifically, the principles, which as defined by Kellert and Calabrese, are fundamental.

3 Methodology

3.1 Developing a framework for assessing biophilic implementations

The aim of this paper is to investigate how and why biophilia is implemented in urban environments for improved health and wellbeing, by developing a holistic biophilic framework for its evaluation. Four case studies were selected, assessed for their design strategies and biophilic applications. The case studies were selected from the RIBA awards, "The RIBA National Awards are given to buildings across the UK recognised as significant contributions to architecture" (RIBA, 2018, p. 1). The case studies are all projects which were recently completed and provide a good indication of the extent of which biophilia is implemented to promote health and wellbeing. The criteria for selection were large to medium sized buildings in the UK, located in urban areas, from a variety of settings: educational, office spaces and dwellings.

As a new biophilic framework is necessary for the holistic application of biophilia, which is lacking in current GBRT and Health and Wellness standards, concepts and theories proposed by experts in the field of biophilia were assessed and compared. The state-of-the-art literature reviewed in Section 2 formed the basis for the elaboration of a holistic biophilic framework based on Kellert and Calabrese. (see chart 1 "Practice of Biophilic Design). The framework is represented in the form of tables, one for the experiences and attributes and another for the principles (see Table 2).

- Stage 1: Kellert and Calabrese's experiences and application of biophilic design (2015, p. 6-20).

- Stage 2: Kellert and Calabrese's biophilic principles (2015, p. 6-7).

The data was collected from images, project descriptions from the architect's websites, RIBA website along with observations from videos and images to evaluate the application of biophilia. Case studies were analysed individually and collectively to look for trends and patterns, with results represented categorically through tables.

Experience of direct contact with nature	A	B	C	D
1 Light: natural light, design strategies & materials				
2 Air: natural ventilation, access to outside, operable windows				
3 Water: views of prominent water bodies, fountains, aquaria, wetlands				
4 Plants: abundant ecologically connected vegetation, flowering plants, local species				
5 Animals: design strategies, use of modern technologies to attract and view wildlife				
6 Weather: direct exposure to outside, porches, decks, balconies, gardens				
7 Natural landscapes and ecological features: interconnected plants, animals, water, soil				
8 Fire: fireplaces, creative use of light, colour, movement, and materials of varying heat conductance				

Experience of indirect contact with nature	A	B	C	D
1 Images of nature: images, paintings, sculptures, murals any other representational means				
2 Natural materials: wood, stone, wool, cotton, and leather				
3 Natural colours: earth tones from soil, plants, rocks, sunsets				
4 Simulating natural light and air: design strategies for lighting and ventilation, mimicking natural dynamic qualities				
5 Naturalistic shapes and forms: patterns from nature				
6 Evoking nature: design principles from nature, biomorphic forms				
7 Information richness: diverse environments, options and opportunities				
8 Age change and the patina of time: naturally aging materials, weathering				
9 Natural geometries: mathematical opportunities from nature, self-repeating but varying patterns				
10 Biomimicry: forms and functions inspired from nature				

Experience of space and place	A	B	C	D
1 Prospect and refuge: long views of surrounding settings, safety and security				
2 Organised complexity: orderly and organised complexity				
3 Integration of parts to wholes: central focal points, linking of spaces, clear and discernible boundaries				
4 Transitional spaces: clear and discernible transitional spaces, hallways, porches				
5 Mobility and wayfinding: clear pathways, point of entry, exits				
6 Cultural and ecological attachment to place: culturally relevant design, local landscapes				

Biophilic principles	A	B	C	D
1 Repeated and sustained engagement with nature				
2 Advancing people's health, fitness and wellbeing				
3 Emotional attachment to settings and place				
4 Promotes interactions between people and nature, encourages a sense of relationship and responsibility for the human and natural communities				
5 Interconnected and integrated biophilic architectural solutions				

Table 2: Biophilic Framework, adapted from Kellert and Calabrese (2015, pp. 6-20)

4 Results and discussion

Two investigators evaluated the effectiveness of the holistic biophilic framework. A whose work currently focuses on urban community and productive renovation. Both investigators have knowledge of biophilia and assessed the case

studies for their biophilic features. All results from both investigators were used as this provided valuable information on the framework's effectiveness (see appendix C, D, E).

Four case studies were selected and assessed for their biophilic applications, guided by the framework derived from the literature. The results were checked against the five biophilic principles for a holistic approach to biophilic design. The case studies were analysed individually and collectively to look for trends and patterns, with results represented categorically with tables. This enabled to elaborate theories on the implementation of biophilia in urban environments. The results are summarised below.

4.1 Effectiveness of the holistic biophilic framework in assessing biophilic applications:

Investigator A described the checklist as comprehensive and detailed. Most biophilic features which were implemented or absent were identified by both investigators. Further improvements to the framework have been identified and are as follows:

- Several biophilic design features were similar, causing some confusion to the category the feature belongs, further clarification is required either with detailed subcategories, or by combination of the features. Such as feature 4: Plants: abundant ecologically connected vegetation, flowering plants, local species, and Feature 7: Natural landscapes and ecological features: interconnected plants, animals, water, soil.
- Several biophilic features were unsuccessfully applied, causing some disagreements from the investigators. Especially when assessing the direct experiences of nature, such as plants and water features.
- The biophilic assessment checklist would benefit from including quantifying measures. This could be achieved with the addition of a column, to quantify each feature.
- Field measurements would have improved consistency in the results as some features were unnoticeable from content analysis, such as: the creative uses of nature through artworks and imagery, colours and fabrics.

Furthermore, investigator A suggests images could be implemented to help identify each feature. The framework aimed to provide a holistic assessment of biophilic design in the built environment to improve health and wellbeing. As identified in the literature, a new biophilic assessment tool is required to address

the deficiencies in the built environment. (Kellert et al 2008; Browning et al 2014).

Further adjustments to the framework:

A focus group and a workshop, comprised of academics who were selected for their knowledge and expertise, discussed and assessed the clarity and usefulness of the framework, opinions and recommendations were implemented. (see appendix F for an amended version). Feature 6,9,10 from experience with indirect contact with nature, have been combined with feature 5. This category now represents shapes, forms, patterns, geometries and innovations from nature.

4.2 Holistic biophilic framework: identified trends and patterns in case studies

The trends and patterns identified from the case studies findings suggest biophilia is implemented across all projects through various means. These have been summarised below and include both investigators findings:

- Experiences of direct and indirect contact with nature, along with experiences of space and place, have been implemented across all case studies.
- All three groups of experiences with nature, have been partially implemented to advance people's health, wellbeing and fitness. Both investigators agree that none of the selected, recently completed projects, achieved all five biophilic principles to have a substantial impact on health and wellbeing.
- Across all case studies, experiences of direct contact with nature, through natural lighting and ventilation strategies, were implemented.
- Experiences of direct contact with nature which have the highest benefits for health and wellbeing when assessed against Terrapin Bright's framework, were implemented ineffectively or not at all. Such as prolonged and repeated exposure to nature.
- The biophilic features which benefit health and wellbeing the most, such as direct contact with nature through vegetation, plants, animals, were lacking.
- Biophilia is not an integral part of current environmental assessment standards or health and wellness performance-based standards and certifications. Government incentives should be available to promote biophilic design, to include vegetation, green walls and roofs in urban areas, such as in Singapore.

Although biophilic features were implemented in all case studies, its application fails to meet the five principles, which are fundamental for improving health and wellbeing. This is largely due to implementing vegetation in transitional spaces such as halls, communal and intermediate areas. As previously stated in the literature, the results revealed the biophilic features implemented to improve health and wellbeing were achieved by including thermal comfort, daylighting and ventilation, reflecting the importance of energy efficiency measures, and health and wellbeing in the current standard assessment methods. However, in most case studies the experience of direct contact to nature such as plants: abundant ecologically connected vegetation, flowering plants and local species were lacking. Plants, green walls, lawns were disconnected. If biophilia is to be implemented for health and wellbeing, this should be reflected in the choice and selection of its application. Although building occupants had access to direct contact with nature, many spaces were devoid of biophilic features.

5 Conclusion

The findings from the holistic biophilic framework inspired by Kellert and Calabrese, provided several key theories on the application of biophilic design: biophilia is acknowledged and implemented in urban environments but lacks a holistic approach. Biophilic features were applied in all case studies, however its application is limited to transitional and intermediate spaces. Repeated and sustained engagement with nature is lacking in most case studies, nature is mostly implemented as an “added feature” rather than an integral part of the structure. This is further verified when compared to truly biophilic buildings from the literature such as in Singapore. None of the case studies selected achieved all five biophilic principles for its successful implementation, as defined by Kellert and Calabrese.

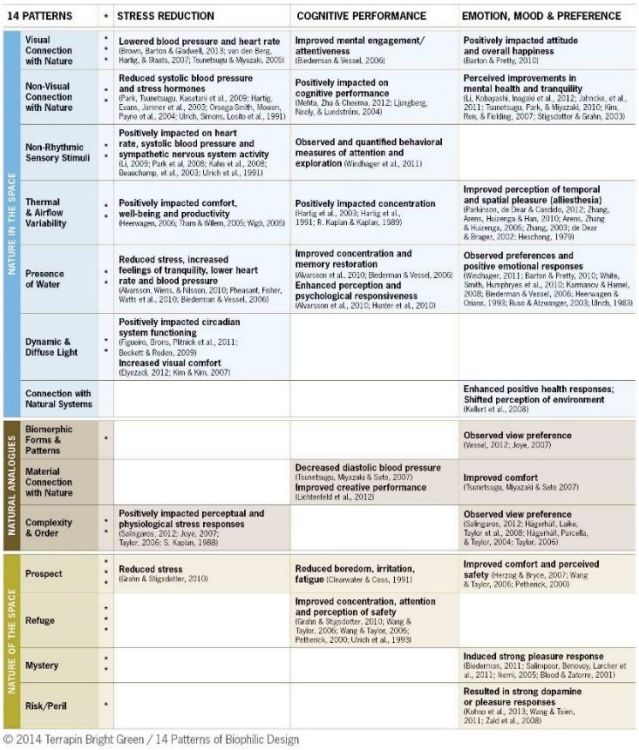
Biophilia is implemented in recent projects and contributes to improved health and wellbeing, however its application lacks the holistic approach for its successful implementation as defined by researchers. Furthermore, its acknowledgment is growing and being recognised for its health and wellbeing benefits but also as a replacement for sustainable design. Additionally, its application needs further definition, biophilia should be consciously implemented with the knowledge that it improves health and wellbeing when implemented holistically, rather than just added as a last thought. Direct contact with nature is the most beneficial biophilic feature to improve health and wellbeing, however natural ventilation and daylighting seem to be the main direct experiences applied

in recently completed projects. The most beneficial features of biophilic design to improve health and wellbeing are implemented ineffectively due to site constraints, lack of acknowledgment, and the lack of incentives, especially when compared to biophilic cities such as Singapore.

5. 1 Recommendations identified from this paper are as follows:

- A quantitative approach for the evaluation of biophilia, using field measurements would provide a consistent method for the assessment of biophilic features.
- A holistic biophilic framework which include the principles as defined in the literature, should be included in environmental standards and health and wellness performance-based certification.
- Further research into the benefits of indirect contact with nature along with the effect of nature to other senses are required.

Appendix A: Terrapin Bright Green's 14 Biophilic Patterns and Health and Wellbeing Outcomes.



	14 PATTERNS	*	STRESS REDUCTION	COGNITIVE PERFORMANCE	EMOTION, MOOD & PREFERENCE
NATURE IN THE SPACE	Visual Connection with Nature	* * *	**Lowered blood pressure and heart rate** (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005)	**Improved mental engagement/ attentiveness** (Biederman & Vessel, 2006)	**Positively impacted attitude and overall happiness** (Barton & Pretty, 2010)
	Non-Visual Connection with Nature	* *	**Reduced systolic blood pressure and stress hormones** (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003; Orsega-Smith, Mowen, Payne et al., 2004; Ulrich, Simons, Losito et al., 1991)	**Positively impacted on cognitive performance** (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004)	**Perceived improvements in mental health and tranquility** (Li, Kobayashi, Inagaki et al., 2012; Jahncke, et al., 2011; Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003)
	Non-Rhythmic Sensory Stimuli	* *	**Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity** (Li, 2009; Park et al. 2008; Kahn et al., 2008; Beauchamp, et al., 2003; Ulrich et al., 1991)	**Observed and quantified behavioral measures of attention and exploration** (Windhager et al., 2011)	
	Thermal & Airflow Variability	* *	**Positively impacted comfort, well-being and productivity** (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005)	**Positively impacted concentration** (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989)	**Improved perception of temporal and spatial pleasure (aliesthesia)** (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002; Heschong, 1979)
	Presence of Water	* *	**Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure** (Alvarsson, Wiens, & Nilsson, 2010; Pheasant, Fisher, Watts et al., 2010; Biederman & Vessel, 2006)	**Improved concentration and memory restoration** (Alvarsson et al., 2010; Biederman & Vessel, 2006) **Enhanced perception and psychological responsiveness** (Alvarsson et al., 2010; Hunter et al., 2010)	**Observed preferences and positive emotional responses** (Windhager, 2011; Barton & Pretty, 2010; White, Smith, Humphryes et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Heerwagen & Orians, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983)
	Dynamic & Diffuse Light	* *	**Positively impacted circadian system functioning** (Figueiro, Brons, Plitnick et al., 2011; Beckett & Roden, 2009) **Increased visual comfort** (Dyrezadi, 2012; Kim & Kim, 2007)		
	Connection with Natural Systems				**Enhanced positive health responses; Shifted perception of environment** (Kellert et al., 2008)
NATURAL ANALOGUES	Biomorphic Forms & Patterns	*			**Observed view preference** (Vessel, 2012; Joye, 2007)
	Material Connection with Nature			**Decreased diastolic blood pressure** (Tsunetsugu, Miyazaki & Sato, 2007) **Improved creative performance** (Lichtenfeld et al., 2012)	**Improved comfort** (Tsunetsugu, Miyazaki & Sato 2007)
	Complexity & Order	* *	**Positively impacted perceptual and physiological stress responses** (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988)		**Observed view preference** (Salingaros, 2012; Hägerhäll, Laike, Taylor et al., 2008; Hägerhäll, Purcell, & Taylor, 2004; Taylor, 2006)
NATURE OF THE SPACE	Prospect	* * *	**Reduced stress** (Grahn & Stigsdotter, 2010)	**Reduced boredom, irritation, fatigue** (Clearwater & Coss, 1991)	**Improved comfort and perceived safety** (Herzog & Bryce, 2007; Wang & Taylor, 2006; Petherick, 2000)
	Refuge	* * *		**Improved concentration, attention and perception of safety** (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006; Wang & Taylor, 2006; Petherick, 2000; Ulrich et al., 1993)	
	Mystery	* *			**Induced strong pleasure response** (Biederman, 2011; Salingaros, Brkovic, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001)
	Risk/Peril	*			**Resulted in strong dopamine or pleasure responses** (Kohno et al., 2013; Wang & Tsien, 2011; Zald et al., 2008)

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Figure A: Biophilic Patterns and Biological Responses. Figure reproduced from (Terrapin Bright Green 2015, p.1)

Appendix B: Biophilic Pathways to Urban Resilience

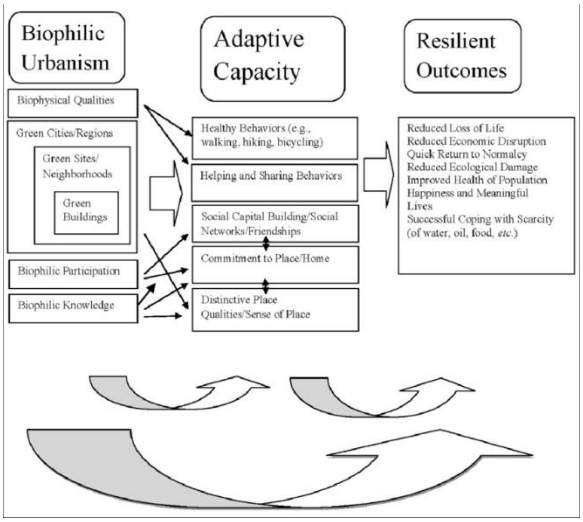

Figure B: Biophilic Pathways to Urban Resilience. Figure reproduced from (Beatley & Newman 2013. p-3333)

Appendix C: Biophilic framework results – Investigator A

Experience of direct contact with nature	A	B	C	D
1 Light: natural light design strategies & materials	√		√	√
2 Air: natural ventilation, access to outside, operable windows	√	√	√	√
3 Water: views of prominent water bodies, fountains, aquaria, wetlands	√			
4 Plants: abundant ecologically connected vegetation, flowering plants, local species	√			√
5 Animals: design strategies, use of modern technologies to attract and view wildlife				√
6 Weather: direct exposure to outside, porches, decks, balconies, gardens	√			√
7 Natural landscapes and ecological features: interconnected plants, animals, water, soil	√			√
8 Fire: fireplaces, creative use of light, colour, movement, and materials of varying heat conductance	√	√		√

Experience of indirect contact with nature	A	B	C	D
1 Images of nature: images, paintings, sculpture, murals other representational means		√		
2 Natural materials: wood, stone, wool, cotton, and leather		√		√
3 Natural colours: earth tones from soil, plants, and rocks, sunsets		√		
4 Simulating natural light and air: design strategies for lighting and ventilation, mimicking natural dynamic qualities		√	√	
5 Naturalistic shapes and forms: patterns from nature		√		
6 Evoking nature: design principles from nature, biomorphic forms		√		
7 Information richness: diverse environments, options and opportunities	√	√		√
8 Age change and the patina of time: naturally aging materials, weathering				
9 Natural geometries: mathematical opportunities from nature, self-repeating but varying patterns.	√			
10 Biomimicry: forms and functions inspired from nature				

Experience of space and place	A	B	C	D
1 Prospect and refuge: views of surrounding settings, safety and security				√
2 Organised complexity: orderly and organised complexity	√	√	√	√
3 Integration of parts to a whole: central focal points, linking of spaces, clear and discernible boundaries		√	√	√
4 Transitional spaces: clear and discernible transitional spaces, hallways, porches	√	√	√	√
5 Mobility and wayfinding: clear points for pathways, entries and exits.	√	√	√	√
6 Cultural and ecological attachment to place: culturally relevant design, local landscapes		√	√	√

Biophilic principles	A	B	C	D
1 Repeated and sustained engagement with nature	√			√
2 Advancing people's health, fitness and wellbeing	√	√	√	√
3 Emotional attachment to settings and place	√	√	√	√
4 Promotes interactions between people and nature, encourages a sense of relationship and responsibility for the human and natural communities	√			√
5 Interconnected and integrated biophilic architectural solutions		√		

Appendix D: Biophilic framework results – Investigator B

Experience of direct contact with nature	A	B	C	D
1 Light: natural light design strategies & materials.	✓	✓	✓	✓
2 Air: natural ventilation, access to outside, operable windows.	✓	✓	✓	✓
3 Water: views of prominent water bodies, fountains, aquaria, wetlands…	✓	✓		
4 Plants: abundant ecologically connected vegetation, flowering plants, local species.				
5 Animals: design strategies, use of modern technologies to attract and view wildlife				✓
6 Weather: direct exposure to outside, porches, decks, balconies, gardens.	✓		✓	✓
7 Natural landscapes and ecological features: interconnected plants, animals, water, soil	✓			
8 Fire: fireplaces, creative use of light, colour, movement, and materials of varying heat conductance.	✓	✓		✓

Experience of indirect contact with nature	A	B	C	D
1 Images of nature: images, paintings, sculpture, murals other representational means		✓		✓
2 Natural materials: wood, stone, wool, cotton, and leather	✓	✓	✓	
3 Natural colours: earth tones from soil, plants, and rocks, sunsets		✓		✓
4 Simulating natural light and air: design strategies for lighting and ventilation, mimicking natural dynamic qualities	✓	✓	✓	✓
5 Naturalistic shapes and forms: patterns from nature		✓		✓
6 Evoking nature: design principles from nature, biomorphic forms		✓		
7 Information richness: diverse environments, options and opportunities	✓	✓	✓	✓
8 Age change and the patina of time: naturally aging materials, weathering		✓		✓
9 Natural geometries: mathematical opportunities from nature, self-repeating but varying patterns.		✓		
10 Biomimicry: forms and functions inspired from nature		✓		

Experience of space and place	A	B	C	D
1 Prospect and refuge: views of surrounding settings, safety and security			✓	
2 Organised complexity: orderly and organised complexity	✓	✓		
3 Integration of parts to a whole: central focal points, linking of spaces, clear and discernible boundaries	✓	✓	✓	✓
4 Transitional spaces: clear and discernible transitional spaces, hallways, porches	✓	✓	✓	✓
5 Mobility and wayfinding: clear points for pathways, entries and exits.	✓	✓	✓	✓
6 Cultural and ecological attachment to place: culturally relevant design, local landscapes	✓	✓	✓	✓

Biophilic principles	A	B	C	D
1 Repeated and sustained engagement with nature				
2 Advancing people's health, fitness and wellbeing	✓	✓	✓	✓
3 Emotional attachment to settings and place	✓	✓		
4 Promotes interactions between people and nature, encourages a sense of relationship and responsibility for the human and natural communities	✓		✓	✓
5 Interconnected and integrated biophilic architectural solutions		✓		✓

Appendix E: Combined results

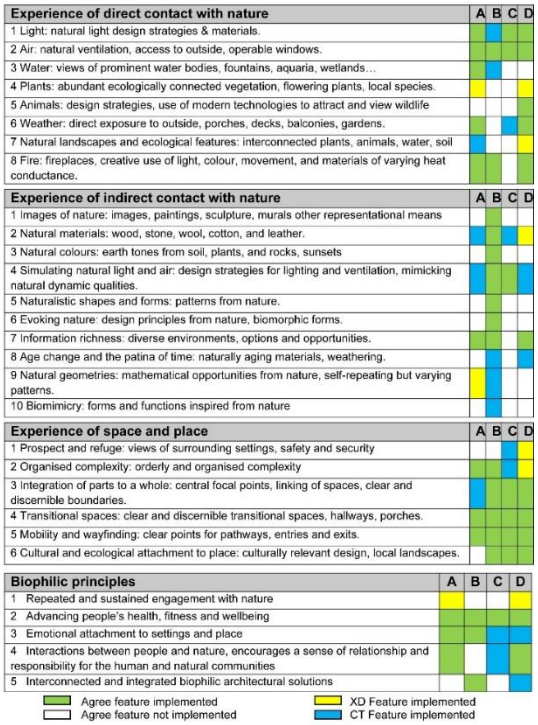

Table 1: Combined Findings

Appendix F: Amended framework from focus group

Experience of direct contact with nature	A	B	C	D
1 Light: natural light, reflective materials and design strategies…				
2 Air: natural ventilation, access to outside, engineering strategies…				
3 Water: views of prominent water bodies, fountains, aquaria, constructed wetlands…				
4 Plants: abundant ecologically connected vegetation, flowering plants, local species…				
5 Animals: contact with local species/animal life, technologies to attract/view wildlife…				
6 Weather: exposure to outside conditions, porches, decks, balconies, gardens…				
7 Natural landscapes & ecosystems: biological diversity, ecological services, interactions and participation with nature…				
8 Fire: fireplaces, creative use of light, colour, movement, materials of varying heat conductance…				

Experience of indirect contact with nature	A	B	C	D
1 Images of nature: images, paintings, sculptures, murals, other representational means...				
2 Natural materials: wood, stone, wool, cotton, leather …				
3 Natural colours: earth tones from soil, plants, and rocks, sunsets…				
4 Simulating natural light and air: design strategies for lighting and ventilation which mimic natural dynamic qualities and variances…				
5 Nature inspired designs: patterns, geometries from nature, biomorphism, biomimicry…				
6 Information richness: information-rich and diverse environments, options & opportunities				
7 Age, change, and the patina of time: naturally aging materials, weathering, passage of time…				

Experience of space and place	A	B	C	D
1 Prospect and refuge: long views of surrounding settings, safety and security…				
2 Organised complexity: diverse and varied spaces, connection and coherence…				
3 Integration of parts to wholes: central focal points, linking of spaces, clear and discernible boundaries…				
4 Transitional spaces: clear and discernible transitional spaces, hallways, porches, patio…				
5 Mobility and wayfinding: clear pathways, points of entry, exits…				
6 Cultural and ecological attachment to place: culturally relevant design, local landscapes.				

Biophilic principles	A	B	C	D
1 Repeated and sustained engagement with nature.				
2 Advancing people's health, fitness and wellbeing.				
3 Emotional attachment to settings and place.				
4 Promotes interactions between people and nature, encourages a sense of relationship and responsibility for the human and natural communities.				
5 Mutual reinforcing, interconnected and integrated architectural solutions.				

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