School of Design and the Built Environment

Delivering Biophilic Urbanism: Tools and Strategies for Implementation

Agata Cabanek

This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

October 2021

Author's Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number HRE2016-0258.

Signature:

Date: 29th of September 2021

Statement of contributors

All of the written materials submitted as part of this PhD by publication (hybrid) were conceived and coordinated by Agata Cabanek. Agata also undertook the majority of the writing and analysis for each publication.

Signed:

Agata Cabanek, PhD Candidate Date: 29th of September 2021

Professor Peter Newman, Principal Supervisor Date: 29th of September 2021

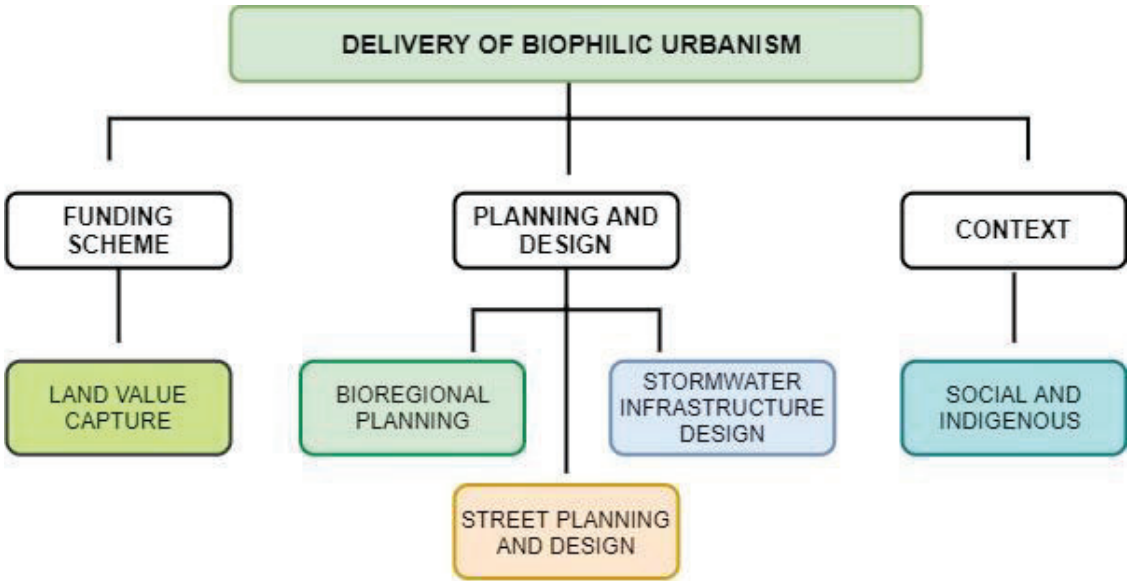
Abstract

Global interest in biophilic urbanism and design is growing, but this planning and design approach remains niche. A number of cities around the world are working towards becoming more biophilic by introducing biophilic design strategies into various policies and joining organisations such as the Biophilic Cities Network. This thesis is designed to support that process and contribute to the academic consideration of this new approach to cities.

The thesis evaluates potential strategies and tools for the efficient and financially-viable delivery of biophilic urbanism and biophilic design. By developing strategies and tools to facilitate the implementation of biophilic urbanism, this thesis argues that it becomes possible to deliver healthier and more liveable urban environments as well as habitats that support urban wildlife.

This thesis consists of five publications supported by an exegesis. In combination, they explore the tools, attributes, design elements, approaches, values, incentives and drivers facilitating the delivery of biophilic urban regeneration projects.

The five papers are organised according to three implementation strategies: funding, planning and design and context, as set out in the Figure below.



The first paper, “Biophilic urban regeneration: can biophilics be a land value capture mechanism?”, sets out how the concept of land value capture, now commonly used in

delivering transport projects, can be applied to biophilic urbanism projects and assist with securing funding.

The second paper, “Bioregional Planning and Biophilic Urbanism”, shows how traditional bioregional planning can be adapted to bring a more biophilic urbanism outcome through applying its principles in an urban context.

The third paper, “Biophilic streets: a design framework for creating multiple urban benefits”, draws on the principles of new urbanism-based street planning to enable biophilic urbanism to be built into this approach to street revitalisation.

The fourth paper, “Regenerating stormwater infrastructure into biophilic urban assets. Case studies of a sump garden and a sump park in Western Australia”, considers a stormwater project to show how some core implementation principles of local planning and design—community-engagement, specialised design expertise, creativity and local government commitment—can be applied to biophilic urbanism.

The fifth paper, “Indigenous Landscaping and Biophilic Urbanism: Case Studies in Noongar Six Seasons”, shows how the concepts of regional indigenous landscape approaches can be applied to biophilic urbanism in an urban context.

A multiple-case study research approach was used to answer the main question and the sub-questions posed in this thesis. This methodology refers to several instrumental bounded cases that were selected to develop a more in-depth understanding of multiple issues. This approach was also selected to facilitate a theoretical analysis of a broader context.

The multiple-case design allows the examination of processes and results across a number of selected cases, and the identification of how each is affected by similar conditions and factors. The case studies and project examples used in this thesis are mainly exploratory and were selected to illustrate the most effective implementation strategies and tools for the delivery of biophilic urban projects.

This exegesis considers and integrates the ideas examined in the five papers towards achieving the fluid delivery and mainstreaming of biophilic urbanism. The overriding goal is to transform biophilic urbanism from being a niche urban design strategy to one that can be applied systematically at different scales, to individual buildings and to entire cities. Understanding the values, incentives, tools, drivers and constraints in the planning and delivery of urban biophilic infrastructure will provide urban planners and stakeholders with a basis for enabling and stimulating wider up-take.

Acknowledgements

I acknowledge that Curtin University works across hundreds of traditional lands and custodial groups in Australia, and with First Nations people around the globe. I wish to pay my deepest respects to their ancestors and members of their communities, past, present, and emerging leaders.

I would like to acknowledge the essential funding support I received from the CRC for Low Carbon Living.

I wish to thank many people for their support and encouragement during my PhD studies.

First of all, I would like to thank my supervisor Professor Peter Newman for his support and guidance, optimism and inspiration. You believed in me when I didn't believe in myself. Thank you for identifying the need for this research project and for your leadership along the way.

Thank you to my co-supervisors Dr Maria Elena Zingoni de Baro and Dr Mike Mouritz for your support and discussions along the way. Thank you for being great advisors and mentors. Mariela – thank you for the teaching exposure you gave me in your classes.

Professor Greg Morrison, thank you for your support and many hours of interesting discussions, and your unique sense of humour!

To my co-authors for the publications in this thesis – Professor Peter Newman, Dr Maria Elena Zingoni de Baro, Dr Joshua Byrne and Dr Noel Nannup – thank you for all your insightful conversations and inputs into our publications.

Thank you to the CUSP community – Christine Finlay and Imran Khan for your support in navigating through the admin processes. To my fellow CUSPians and PhD hubbies Sebastian, Jane, Jess, Lil, Moiz, Simone, Lio, Christine, Stephen, Negar and many others from the Humanities Research Hub – for your friendship, support, mentoring and hugs. I would have never made it this far without you!

Finally, to my family and friends supporting me along the way and asking the one question that every PhD student loves: ‘Have you finished your PhD yet?’ After five years, the answer is ‘Yes! I have finished!’

So, let a new chapter begin!

Dedication

To my grandparents,

Janina and Marian Bulak

Janina and Stanislaw Cabanek

whose dreams of education were violently shattered

on the 1st of September 1939

when the Nazi army invaded Poland

List of publications included in the thesis

The following publications are the basis of this thesis and are provided as appendices following the exegesis. The publications are referred to in the exegesis in roman numerals. Copyright statements for published materials can be found in Appendices C to G.

Refereed Conference Proceedings

Cabanek, A. & Newman, P. (2016). Biophilic urban regeneration: can biophilics be a land value capture mechanism? In C.A. Brebbia, S.S. Zubir & A.S. Hassan (Eds.), *WIT Transactions on Ecology and the Environment. Sustainable Development and Planning* (pp. 65-78). Doi: 10.2495/SDP160061

Refereed Journal Articles

Cabanek, A., Zingoni de Baro, M.E. & Newman, P. (2020). Biophilic streets: a design framework for creating multiple urban benefits. *Sustainable Earth*, 3(7), https://doi.org/10.1186/s42055-020-00027-0

Cabanek, A., Zingoni de Baro, M. E., Byrne, J., & Newman, P. (2021). Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia. *Sustainability*, *13*(10), 5461. http://dx.doi.org/10.3390/su13105461

Cabanek, A., Newman, P. & Nannup N. (2021). Indigenous Landscaping and Biophilic Urbanism: Case Studies in Noongar Six Seasons. *Submitted to Sustainable Earth*

Refereed Book Chapters

Newman P. & **Cabanek A.** (2020) Bioregional Planning and Biophilic Urbanism. In D. Fanfani & A. Matarán Ruiz (Eds.), *Bioregional Planning and Design: Volume I*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-45870-6_7

Co-authors' statements

Publication I

I, Agata Cabanek, contributed 60% to the publication entitled:

Cabanek, A. & Newman, P. (2016). Biophilic urban regeneration: can biophilics be a land value capture mechanism? In C.A. Brebbia, S.S. Zubir & A.S. Hassan (Eds.), *WIT Transactions on Ecology and the Environment. Sustainable Development and Planning* (pp. 65-78). Doi: 10.2495/SDP160061

The contribution entailed initial discussions of the paper concept, undertaking the literature review and analysis of the literature, methodology design, data collection, data analysis, writing and editing of the paper, including minor revisions.

Signature of Candidate: *Date: 10/08/2021*

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co-author: Peter Newman

Signature: *Date: 10/08/2021*

Publication II

I, Agata Cabanek, contributed 60% to the publication entitled:

Newman P. & **Cabanek A.** (2020) Bioregional Planning and Biophilic Urbanism. In D. Fanfani & A. Matarán Ruiz (Eds.), Bioregional Planning and Design: Volume I. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-45870-6_7

The contribution entailed initial discussions of the paper concept, undertaking the literature review and analysis of the literature, writing and editing of the paper, including minor revisions.

Signature of Candidate: *Date: 10/08/2021*

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co-author: Peter Newman

Signature: *Date: 10/08/2021*

Publication III

I, Agata Cabanek, contributed 70% to the publication entitled:

Cabanek, A., Zingoni de Baro, M.E. & Newman, P. (2020). Biophilic streets: a design framework for creating multiple urban benefits. *Sustainable Earth*, 3(7), https://doi.org/10.1186/s42055-020-00027-0

The contribution entailed initial discussions of the paper concept, undertaking the literature review and analysis of the literature, methodology design, data collection, data analysis, writing and editing of the paper, including minor revisions.

Signature of Candidate: *Date: 10/08/2021*

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co-author 1: Maria Elena Zingoni de Baro

Signature: *Date: 10/08/2021*

Co-author 2: Peter Newman

Signature: *Date: 10/08/2021*

Publication IV

I, Agata Cabanek, contributed 70% to the publication entitled:

Cabanek, A., Zingoni de Baro, M. E., Byrne, J., & Newman, P. (2021). Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia. *Sustainability*, *13*(10), 5461. http://dx.doi.org/10.3390/su13105461

The contribution entailed initial discussions of the paper concept, undertaking the literature review and analysis of the literature, methodology design, data collection, data analysis, writing and editing of the paper, including minor revisions.

Signature of Candidate: *Date: 10/06/2021*

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co-author 1: Maria Elena Zingoni de Baro
Signature: *Date: 10/06/2021*

Co-author 2: Joshua Byrne
Signature: *Date: 10/06/2021*

Co-author 3: Peter Newman

Signature: *Date: 10/06/2021*

Publication V

I, Agata Cabanek, contributed 70% to the publication entitled:

Cabanek, A., Newman, P. & Nannup N. (2021). Indigenous Landscaping and Biophilic Urbanism: Case Studies in Noongar Six Seasons. *Submitted to Sustainable Earth*

The contribution entailed initial discussions of the paper concept, undertaking the literature review and analysis of the literature, methodology design, data collection, data analysis, writing and editing of the paper, including minor revisions.

Signature of Candidate: *Date: 30/08/2021*

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co-author 1: Peter Newman

Signature: *Date: 30/08/2021*

Co-author 2: Noel Nannup

Signature: *Date: 30/08/2021*

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

BD	Biophilic Design
BREEM	Building Research Establishment Environmental Assessment Method
BU	Biophilic Urbanism
BUD	Biophilic Urban Design
CABE	Design Council Cabe
EU	European Union
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
NABRES	National Australian Built Environment Rating System
SBEnrc	Sustainable Built Environment National Resource Centre
SDGs	Sustainable Development Goals
UN	United Nations
WGV	White Gum Valley

Chapter 1 Introduction

This thesis investigates the methods and strategies for implementing biophilic urbanism (BU) in urban environments. In such environments, the land available for quality green spaces is becoming increasingly scarce due to densification or other urbanisation processes that have removed their natural qualities.

The exegesis component of this thesis presents the context for my work, contained in five papers, and provides an opportunity to explore wider issues pertaining to theory, policy and practice. It also collates and integrates the publications and outlines the scope of the research.

This introductory chapter provides the background to five research questions. These questions are addressed through three peer reviewed publications and two manuscripts submitted to peer reviewed journals.

1.1 Research Context

This section provides the research background and justifies the need for this research. It outlines the theoretical issues and discusses this research in relation to previous studies.

1.1.1 Background

By 2050, 70% of the world's population will become urban dwellers (UN HABITAT, 2009). Australia has one of the most urbanised populations in the world, with more than 75% of people living in cities and large towns (Australian Government, 2010b). According to Treasury's estimates, the Australian population is forecast to grow from 23 million to some 35 million by 2050 (Australian Government, 2010a). To accommodate the growing urban population, authorities in Australian cities and around the world have been employing new development strategies. Urban planners and designers use sustainable development strategies to provide design proposals that aim at achieving healthy living environments (Beatley, 2012, 2016b; Kitchen, 2000; Wiktorowicz et al., 2018). However, room for improvement remains, as current policies and design standards fail to provide universal wellbeing and environmental justice (Birkeland, 2018; Duncan et al., 2013; Reil & Balenciaga, 2019).

Sprawling urbanisation has negative implications for the quality of urban living (Nechyba & Walsh, 2004; Wolff & Haase, 2019). Climate change exacerbates the negative impact of urban sprawl on human wellbeing and on urban ecosystems (Frenkel, 2004; B. Wilson & Chakraborty, 2013). Nature loss within urbanised areas and bioregions brings a high number of climate related risks to communities, such as heat island effect, increasing energy demands for cooling and heating, flash-floods, and higher concentrations of carbon dioxide. Pursuing entrenched developmental and economic strategies may lead to increased frequency of catastrophic events; for example, the bush fires and floods in Australia in 2019 (Norman et al., 2021). Climate change related catastrophes threaten the existence of ecosystems and civilisation and result in significant economic, environmental and social loss (Bruyère et al., 2020). To halt or reverse the negative impacts of urban sprawl and its damaging impact on human and environmental health, a unified approach to urban and regional planning is needed (Newman & Jennings, 2008).

Increased density, avoiding urban sprawl, and active transport are some of the main strategies for a more sustainable urban future. A consequence of increasing density and urban infill, however, is a decrease in the availability of land for quality green spaces (Wolff & Haase, 2019). In Australia, private gardens and green backyards have become a luxury commodity and serve a limited number of urban residents (Hall, 2010). Gardens and green backyards are being replaced by new houses. As societies become more aware of climate and environment issues and choose to implement new sustainability solutions in houses, developers often follow the guidelines of organisations offering certifications or accreditation to validate green credentials (for example, BREEM, LEED, NABRES, Green Star). However, as Jan Gehl pointed out in his book Cities for People (Gehl, 2010), an endless number of green buildings does not make a sustainable city. Instead, the core of sustainable urban design should be designing for people, and urban fauna and flora. Therefore, high-quality green spaces and places full of nature and its analogues must be planned and designed for densifying cities in order to meet the demands of sustainable urban living (Beatley, 2016a; Beatley & Newman, 2013; Kellert et al., 2008; Newman, 2014).

In terms of urban economies, our current economic system has failed to value nature (European Parliament, 2016; IPBS, 2019), including urban nature. Assigning an economic value to the urban greenery is still difficult to establish (Mell et al.,

2013). Urban developers budget predominantly for buildings and grey infrastructure, with a proportionally smaller investment for accompanying green infrastructure. However, many case studies have shown that investing in quality green infrastructure can produce significant revenue for developers and the wider community (Ascher & Uffer, 2015; David & Hammond, 2011; Mell, 2019; Mell et al., 2016). Still, a framework for financing green, especially biophilic infrastructure, needs to be developed in relation to the location and size of a development. One possible method for financing quality green infrastructure is a land value capture mechanism. This mechanism has already been considered as a framework for developing light railways in cities (Newman, 2015; Newman et al., 2018).

Biophilic design (BD) places economic, environmental, health and social issues at the heart of the creative process. Some research suggests that BU can be a useful paradigm for addressing the challenges posed by cities and urbanised areas; that is, as a means to create or reinforce human-nature relations (Beatley, 2017; Pedersen Zari, 2017; Totaforti, 2020).

BU is based on the knowledge that humans have an innate connection with nature – biophilia - that should be nourished on a daily basis (Beatley, 2011a; Kellert et al., 2008; E. O. Wilson, 1984). BU fosters urban resilience by supporting the engagement between urban nature and residents. This is achieved through sophisticated design and planning of urban natural systems, and the implementation of nature-based solutions, including green infrastructure. Biophilia-based solutions, therefore, can support other urban strategies to mitigate the impact of climate change on the health and wellbeing of human and urban ecosystems (Blau et al., 2018; Fink, 2016).

Although the principles, characteristics and patterns of BD are known to many urban planners and designers (Alexandra & Norman, 2020; Downton et al., 2017; el-Baghdadi & Desha, 2017; Newman et al., 2017b), their full potential has not been mainstreamed in public-realm projects. This is despite the many publications that have analysed case studies in terms of the principles of BD ((Reeve et al., 2013). Some local governments in Australia (City of Bayswater, n.d.; City of Fremantle, n.d.; Town of Bassendean, n.d.) and in other countries (Biophilic Cities Network, n.d.) have considered including BD and BU as tools and strategies to achieve better sustainability and resilience outcomes. Despite growing awareness of the benefits of BU, certain constraints to wider implementation remain. These include the

absence of strong financial mechanisms for delivery, an understanding of the complexity of the associated costs and benefits, integration of biophilic concepts into mainstream planning paradigms, updated regulations and planning requirements, implementation mechanisms, disconnection between urban residents and nature, and path dependency and leadership (Beatley, 2016b; Littke, 2016; SBEnrc, 2012; Wijesooriya & Brambilla, 2020). More research and case study analysis are needed to find solutions and overcome these constraints.

As urban public places become more diverse and multicultural, a better understanding of how various populations use them and what values they attach to them would help urban planners and designers to deploy adequate design tools and solutions. Low et al. (2005) argue that the most successful multicultural public spaces are those for which the identities of different cultural groups are emphasised and celebrated, thereby enabling people of different cultural and ethnic backgrounds to use spaces without fear of discrimination. Culturally appropriate public spaces are essential to the success of a community (Knapp, 2008) and building a sense of place (Yazdani & Lozanovska, 2014). Vibrant neighbourhoods foster social interactions and have a greater level of social capital (Knapp, 2008; Low et al., 2005). It is, therefore, necessary for BU to address the needs of multicultural societies and provide urban places that could build social, economic and ecological capital.

Indigenous people have a long history of deploying nature-based solutions, however, not many countries have recognised this knowledge as crucial to building a sustainable economy and sustainable living environments. The recognition of indigenous knowledge contributions to sustainable and regenerative development is an urgent matter (World Economic Forum, 2020). Regenerative development shares socio-ecological perspectives with BU. It creates ecosystems that integrate natural and human living systems to ensure greater health for both (Mang & Reed, 2012). Indigenous groups in Western Australia recognise that social and ecological systems are strongly interconnected (Wooltorton et al., 2019, 2020). Therefore, meaningful regenerative development can be achieved when the Indigenous people, who have deep connection to a particular place, co-design and co-lead the land care programs.

In order to deliver BU and regenerative development at a city scale, co-designed with multicultural and Indigenous groups, decision-makers and designers need

specific tools and strategies to overcome the obstacles outlined above. Some of these tools and strategies are investigated in this thesis. The principal challenge in delivering such tools and strategies is that they need to be drawn from real-life examples. In addition, good case studies and suitable examples are often located in different cities or countries, which places limitations on data collection. This thesis is based on the analysis of selected case studies and examples of urban infrastructure projects in several cities, and the results provide a foundation for developing frameworks, tools and strategies with wider applicability.

The ecological footprint of humanity on the planet has negatively impacted ecosystems, biodiversity and human health. Without healthy ecosystems and biodiversity, sustainable economic growth is unattainable (World Economic Forum, 2020). How cities are planned and designed now will have a major impact on ecosystems, biodiversity and human health in the future.

1.1.2 Theoretical Framework

The concept of BU is grounded in the biophilia hypothesis developed by E.O. Wilson and Stephen Kellert (E. O. Wilson, 1984). Many research studies have since validated the hypothesis and it has led to a broad field of research has been established by Stephen Kellert, Timothy Beatley, Judith Heerwagen, Bill Browning and others. The biophilia hypothesis states that humans possess an inherent tendency to affiliate with natural systems and processes that reflects human evolution as a species (Kellert, 2012; E. O. Wilson, 1984; E. O. Wilson & Kellert, 1993). Kellert (Kellert, 2016b) defined BU as “the human’s need to affiliate with nature (biophilia) that can be achieved through design strategies and approaches in the built environment (biophilic design), and systematically implemented in cities (biophilic urbanism)”.

Salingaros (Salingaros, 2010) suggests that geometrical structures exist throughout natural systems that support living systems. These structures were perceived by our neural system when we, as a species, lived immersed in nature. As a consequence, the evolution of the human brain was a response to the stimuli provided by natural environments. This primary mental structure is still alive in our brains today and is responsible for nourishing our neural system and keeping us safe and healthy. Salingaros calls this phenomenon the “biophilic effect” (Salingaros, 2019), and it is responsible for providing humans with a deep and genuine connection with nature.

The sense of health, wellbeing and, consequently, the quality of life in buildings and urban realms, depends on how the geometric structures existing in nature are integrated into the design of built environments. This is an essential concept that underpins BD and urbanism and its application can lead to regenerative processes in cities and communities.

Tim Beatley translates the biophilia hypothesis into real world examples of urban interventions that provide a daily dose of nature for urban residents, thereby supporting their health and wellbeing (Beatley, 2016b). The concept intends to answer practical questions around the amount of exposure to nature we need to sustain good health and a positive mood, and what physical forms of nature and its analogues promote these positive responses.

The nature pyramid below (Figure 1.1) depicts what it may take to build “an urban nature diet.” It contains examples of natural elements, settings and experiences providing “a dose of nature,” from discrete elements of an urban nature diet, such as the sight of a bird on a street, to more intense experiences of longer immersion in natural landscapes, such as time in a national park. This particular pyramid was developed by Tanya Denckla-Cobb and Tim Beatley for Singapore (Beatley, 2016b).

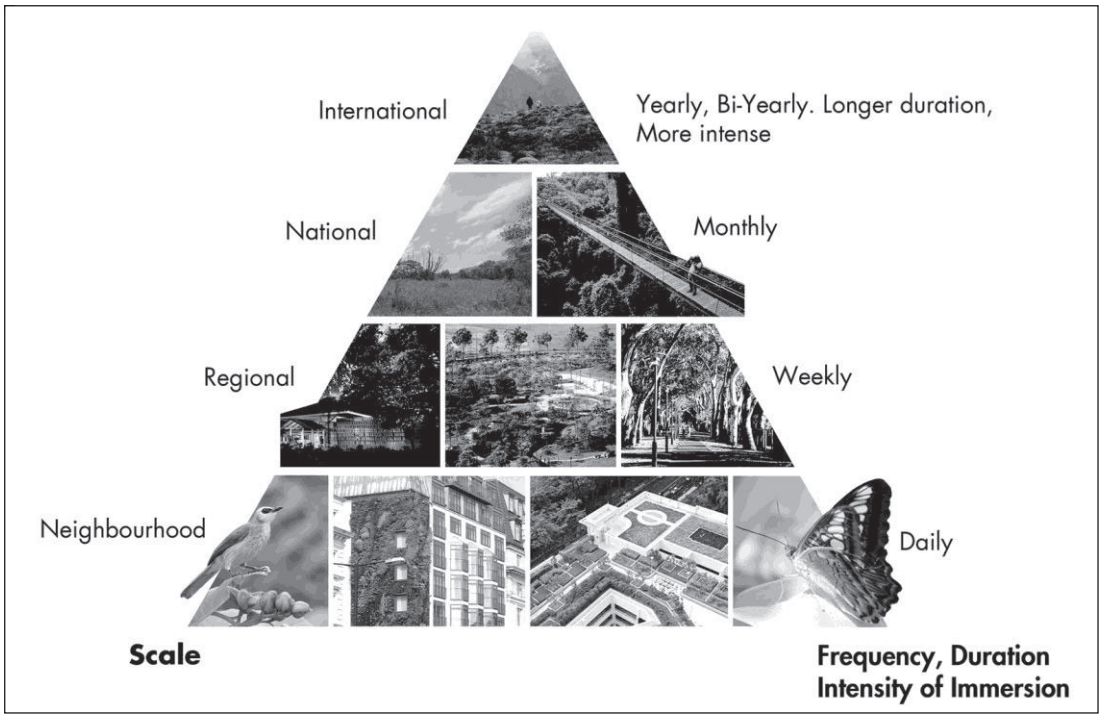


Figure 1.1 The Nature Pyramid for Singapore. Credit: the Singapore National Parks Board.

Kellert (1993) established a typology of human attitudes toward nature and defined nine perspectives that are relevant to the biophilia hypothesis. These nine perspectives or valuations of nature are utilitarian, naturalistic, ecologistic, scientific, aesthetic, symbolic, humanistic, moralistic, dominionistic and negativistic (Table 1.1).

Table 1.1 Biophilia values adopted from Kellert (1993).

TERM	DEFINITION	FUNCTION
Utilitarian	Practical and material exploitation of nature	Physical sustenance and security
Naturalistic	Satisfaction from direct experience or contact with nature	Curiosity, outdoor skills, mental/physical development
Ecologistic/ Scientific	Systematic study of structure, function, and relationship in nature	Knowledge, understanding, observational skills
Aesthetic	Physical appeal and beauty of nature	Inspiration, harmony, peace, security

Symbolic	Use of nature for metaphorical expression, language, expressive thought	Communication, mental development
Humanistic	Strong affection, emotional attachment, “love” for nature	Group bonding, sharing, cooperation, companionship
Moralistic	Strong affinity, spiritual reverence, ethical concern for nature	Order and meaning in life, kinship and affiliative ties
Dominionistic	Mastery, physical control, dominance of nature	Mechanical skills, physical prowess, ability to subdue
Negativistic	Fear, aversion, alienation from nature	Security, protection, safety

The theory of BD and BU is well-developed (Browning et al., 2014; Kellert et al., 2008; Kellert & Calabrese, 2015) and has been extended to an urban scale by Beatley (Beatley, 2011a, 2011b, 2016a) and colleagues (Beatley & Newman, 2013; Newman, 2014); however, the practical tools and strategies of implementing it at a city scale remain unclear. Kellert (Kellert et al., 2008) elaborated a complex framework featuring six categories and seventy attributes of BD. In 2015, Kellert and Calabrese developed a table of biophilic principles to use for design practitioners (Kellert & Calabrese, 2015). Furthermore, Terrapin Bright Green (Browning et al., 2014) developed the “14 patterns of biophilic design,” which offer a useful guide for designers, both for architecture and urban design and planning. The evidence of the biophilic effect (Salingaros, 2010, 2015) on the health and wellbeing of humans provides justification for the development of purposive and systematic strategies to ensure the presence of nature in urban environments.

1.2 Research Positioning

The end of the 20th century brought a number of initiatives attempting to integrate sustainability principles into urban developments. In 1987, the Brundtland Commission proposed sustainable development as a way forward for the world’s economies; related approaches such as green, regenerative and sustainable urbanism emerged soon afterwards (United Nations, 1987). Sustainable urbanism focuses on designing neighbourhoods that are walkable and transit-oriented so that people can meet their daily commuting needs on foot. It promotes solutions for the balanced use of natural resources, such as recycling, renewable green energy and a circular economy, and it recognises ecosystem services as crucial in delivering

and regulating cultural benefits (Newman & Jennings, 2008). One of the concepts of sustainable urbanism, which focuses more on design with nature to create better urban communities, is BU.

BU has also developed from another stream of academic and professional attention, that of healthy cities (de Leeuw et al., 2014; World Health Organization, 2018). The healthy cities research showed that, in cities, nature plays a central role in addressing key global public health challenges associated with urbanisation (Shanahan et al., 2016). However, the advice about how to achieve particular health outcomes from green spaces remains very general (Maller et al., 2008). Initial considerations of how its systematic implementation could improve public life, health and wellbeing began with studies conducted in the United States and Australia (Beatley, 2011a; Beatley & Newman, 2013; Reeve et al., 2013; SBEnrc, 2011).

BU is a broad concept (see Chapter 3 for a more thorough explanation), and recent studies have shown that it—and its practical application through BD—is at times confusing to policymakers, residents and other stakeholders (Beatley, 2016b; Littke, 2016; Reeve et al., 2013).

The issues around positioning BU within urban planning often concern the extent to which it is perceived as a purely ecological approach, or as a purely human (anthropogenic) approach to improving urban civilisation. This may be because it has emerged out of the coalescence of two streams of academic and professional thought in the sustainable urbanism realm on the one hand, and the healthy cities area on the other. Perhaps, however, the strength of BU is that it is an integration of these two perspectives, or development streams, and makes use of the scholarly value and practical insights each brings (Beatley, 2009; Louv, 2005). Thus, a key way to overcome the inability to resolve whether it lies in one realm of practice and thought or the other, is to demonstrate how it is firmly part of both. In his Handbook of Biophilic Design (Beatley, 2016b), Beatley suggests that pilot studies and strong leadership could facilitate wider uptake of BU and better enable its strengths to be recognised. Therefore, “good practice” concepts and real-life project examples are needed to demonstrate how BU can be implemented and understood.

Beatley’s (2011) approach to the integration of BU into practice is based on the idea that nature should be co-designed into urban fabrics at all scales and be present in daily urban life. The idea focuses on enhancing the health and wellbeing of people

through co-designed urban nature, and giving less attention to ecology, environmental conservation or renewable energy, which are considered separated entities. This does not mean that ecology, conservation and renewable energy are not important, but that they can be improved whenever they are part of building cities, rather than being isolated into modernist, detached sectors.

Simaika and Sumways (Simaika & Samways, 2010) argue that because of human preferences for specific landscapes and the proven effectiveness of animal therapy, BU may assist with conservation efforts. Nevertheless, the authors cannot identify any indication that people would appreciate the ecological offerings of certain landscapes, particularly highly artificial urban landscapes. Thus, there does appear to be a greater need for clarity regarding the extent to which BU can be integrated into urban planning overall.

Similar issues pertaining to the comparative emphasis on human or ecological benefits can be seen in the literature. A number of studies have been undertaken which have anthropocentric benefits as their main focus. These studies focus on issues such as reduced stress, increased productivity, longevity, happiness or the prevention or curation of non-communicable disease (Söderlund, 2019). There appear to be fewer published studies giving attention to how BU can benefit urban biodiversity and ecosystems (Reeve et al., 2012). This thesis analyses green infrastructure projects, that enhance local biodiversity, to show how certain implementation principles can be applied to BU.

Biodiversity has been recognised as an essential factor undergirding the delivery of ecosystem services and the economy. Many businesses assess their dependency on biodiversity and plan for its protection and enhancement in their corporate strategies (European Commission, 2011). The New Nature Economy Report (World Economic Forum, 2020) suggests that the industries which depend most on nature are construction (USD4 trillion), agriculture (USD2.5 trillion) and food and beverages (USD1.4 trillion). However, business dependency on urban biodiversity is still under researched and urban nature and biodiversity remain underrated as assets able to generate significant revenue for public or private investors (SBEnrc, 2012; World Economic Forum, 2020). Some examples of biophilic urban regeneration projects analysed in this thesis attempt to show how businesses can contribute to and benefit from biophilic projects through new ways of funding.

Little is known about the extent to which beneficial outcomes for human health and biodiversity can be achieved in the same spaces. The question remains, whether higher levels of vegetation within urban parklands attract or deter visitors. Are people more or less likely to visit parks with greater levels of tree cover or native remnant vegetation? Are they likely to perceive such cover as vegetation with high ecological value? Some current hypotheses describe relationships between health and vegetation complexity; for instance, several studies have found that more people tend to visit public green spaces with moderate levels of vegetation cover (Shanahan et al., 2015). Moreover, higher levels of plant, butterfly and bird species richness (or perceived species richness) are reported to enhance a person's feelings of restoration (Cox et al., 2017; Dallimer et al., 2012).

However, it is still uncertain which characteristics of natural settings (e.g., biodiversity, level of disturbance, proximity or accessibility) are most important for triggering a beneficial interaction, and how these characteristics vary in importance among cultures, geographic regions and socio-economic groups. To minimise potential confusion, the researchers usually focus on specific regions and localities when addressing the importance of aforementioned characteristics (Cruz et al., 2018; Graves Lanfer & Taylor, n.d.; Selin, 2003). These uncertainties signal key directions for research if we are to design urban landscapes that promote high-quality interactions between people and nature in a rapidly urbanising world.

This thesis attempts to contribute to the "integration-through-demonstration" approach with particular focus on tools to deliver economic and environmental benefits of biophilic designs as equally important to anthropocentric benefits. Unavoidably, there will be some confusion evident between the papers that form part of this thesis, as they emphasise more of one side of this integration than the other due to the requirements of particular journals or conferences.

1.3 Thesis Organisation

This thesis consists of five peer-reviewed or submitted publications and an exegesis. The exegesis provides the background and context for this research and a discussion that integrates the publications and locates them, as a whole, within the broader literature and relevant realms of policy and practice. Following the introduction presented in this chapter, Chapter 2 describes the research

methodology and methods. Chapter 3 provides a summary of the literature review, and Chapter 4 presents a brief summary of each publication, their logical progression and interconnections. Chapter 5 provides a summary of the results from the publications as responses to specific research questions, and a general discussion. Finally, Chapter 6 concludes the thesis and offers recommendations for future research. The published articles and the manuscript are provided as appendices following the exegesis.

1.4 Research Questions and Objectives

The overarching research question of this thesis is:

What tools and strategies can help implement BU in a way that integrates human end ecological dimensions?

To answer this question, a number of sub-questions have been proposed:

How can BU be funded?
How can bioregional planning incorporate BU?
How can urban transport planning of streets incorporate BU?
How can urban stormwater engineering incorporate BU?
How can social and indigenous contexts be used to deliver BU?

To address these questions, a series of case study analyses were undertaken, resulting in five publications. The objectives derived from the questions and the associated refereed publications are presented in Table 1.2. Chapter 4 provides a summary of these publications, which comprise the main body of the thesis.

Table 1.2 Summary of the research sub-questions and the associated publications. Credit: Author.

SUB-QUESTIONS	OBJECTIVES	ASSOCIATED PUBLICATIONS
How can BU be funded?	To examine how biophilic elements of different scales can be funded and implemented in urban regeneration projects. To demonstrate how biophilics could be better implemented by governments and private investors as a core factor in urban regeneration projects.	Publication 1: "Biophilic urban regeneration: can biophilics be a land value capture mechanism?" **Published, peer reviewed article in *Sustainable Development and Planning***
How can bioregional planning incorporate BU?	To identify how bioregionalism and BU are related. To show that cities can develop their bioregional strategies from their BD strategies.	Publication 2: "Bioregional planning and BU." **Published, peer reviewed book chapter in *Bioregional Planning and Design***
How can urban transport planning of streets incorporate BU?	To develop a theoretically and practice-informed design framework for biophilic streets to enable effective delivery of BU.	Publication 3: "Biophilic Streets: a framework for creating multiple urban benefits." **Published, peer reviewed article in *Sustainable Earth (Special issue on BU)***
How can urban stormwater engineering incorporate BU?	To develop a framework underpinning the biophilic regeneration of Perth's stormwater infrastructure, taking account of the actors,	Publication 4: "Regenerating stormwater infrastructure into biophilic urban assets. Case studies of a sump garden and a sump

	drivers, strategies, constraints and values. To explore how old stormwater technologies can be regenerated into biophilic urban assets that provide multiple social and environmental benefits. To find a means of integrating regenerative BDs into urban design and planning in a local context such as Perth.	park in Western Australia." **Published, peer reviewed article in *Sustainability (Special Issue: Improving Life in a Changing Urban Environment through Nature-based Solutions and Biophilic Design)***
How can social and indigenous context be used to deliver BU?	To extract principles of Indigenous landscaping that can assist with delivering BU. To examine how indigenous landscaping (knowledge, values, management methods) can be used to assist with delivery of BU.	Publication 5: "Indigenous landscaping and Biophilic Urbanism: case studies of Noongar Six Seasons gardens." **Submitted to *Sustainable Earth***

The first two research sub-questions concern understanding how bioregional planning can incorporate BU and how it can be funded. The next two questions focus on biophilic urban infrastructure design and ask how urban transport planning of streets and adjacent stormwater infrastructure can incorporate and benefit from BU. The last sub-question focuses on urban indigenous landscaping and asks how social and indigenous contexts can be used in BU. These sub-questions led the present investigation towards a deeper understanding of how BU could be effectively mainstreamed and implemented throughout urban landscapes by adopting new funding schemes and re-inventing urban civil and green infrastructure. They all seek to integrate the human and ecological elements of BU.

1.4.1 Scope of Research

The successful delivery of BU is comprised of multiple interrelated factors. To strengthen the scope of this thesis, three implementation strategies have been

selected and are addressed through the five publications. The strategies are presented in Figure 1.2 below:

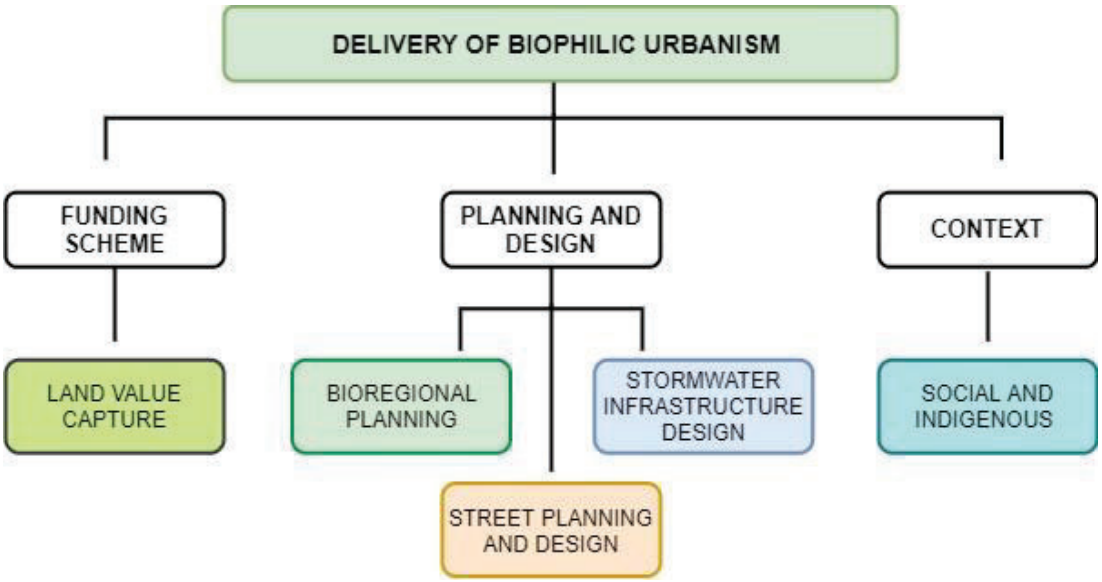


Figure 1.2 Overarching implementation strategies. Credit: Author.

BU needs effective delivery strategies to realise its potential. Therefore, this thesis focuses on finding appropriate avenues to facilitate the successful planning and delivery of biophilic urban interventions. The literature review and selected case studies showcase best practice. The five publications develop and apply the three strategies through the analysis of selected case studies: Publication 1 addresses land capture; Publications 2, 3 and 4 address planning and design; and Publication 5 discusses context. The combined results provide tools and strategies synthesised into frameworks which can be applied to urban biophilic projects and initiatives to support a transition towards BU.

Chapter 2 Methodology and Methods

This chapter presents the methodology and methods employed in the thesis. It poses the main research question: What tools and strategies can help implement BU in a way that integrates human end ecological dimensions?
This research is situated within a qualitative research paradigm and the main approach for answering this question has been to select and analyse multiple case studies which can inform effective and workable tools and strategies to deliver biophilic objectives in the urban realm that integrate human and ecological aspects. Identified tools and strategies form the basis for the frameworks (Publications 3 and 4) and principles (Publications 1, 2 and 5) that can be used by design professionals and decision-makers to mainstream and deliver biophilic projects. This explanatory research is also seeking to develop an understanding of the process of change leading to the adoption of BU strategies to deliver biophilic experiences at a city scale.

2.1 Research Methodology

The overall methodology used in this research project is based on a case study approach of empirical inquiry. The case study research methodology draws on and is guided by the approach outlined by Yin (Yin, 2018), Francis (1999) and Swaffield and Deming (2011). This approach uses multiple forms of data collection for an in-depth exploration of a specific system, process or area of decision-making in order to understand how the case studies function within its real-world context (Francis, 1999; Mills et al., 2012; Yin, 2018). In the design professions, such as landscape architecture and urban design, case studies are used to describe or evaluate projects after construction (Francis, 1999). Within a particular project, the research task focuses on the aforementioned systems, processes and outcomes, as well as design elements and techniques. According to Francis (1999), the case study analysis should occupy a central role in landscape architectural practice, education and research. It is, therefore, suitable for research on the delivery of BU to use this methodology and related methods.

Case studies in landscape architecture and urban design can be used to develop strategic approaches and tools for future biophilic projects from the scale of a singular façade of a building to the scale of a region (Publications 1-5).The selected

case study and project examples were conducted and organised around the research sub-questions.

2.1.1 Multi-Case Study Research Design

A multiple-case study research approach was used to answer the main research question and sub-questions posed in this thesis (Figure 2.1). This methodology refers to several instrumental bounded cases which were selected to develop a more in-depth understanding of single or multiple issues (Publications 1, 3, 4 and 5), but also to theorise about a broader phenomenon (Publication 2; Mills et al., 2012; Yin, 2018).

Multiple-case design allows examination of processes and results across a number of selected cases. This approach allows identification of how each case can be affected by similar conditions and factors. Two variants of multiple-case studies were used, with a single unit of analysis (example: cost-benefit project analysis in Publication 1 and multiple units of analysis in Publications 2, 3, 4 and 5).

The case studies and project examples used in this thesis are mainly explanatory. They feature urban planning approaches and design solutions that justify the decision to use the case study method developed by Francis (1998) for landscape architecture. The chosen case studies and exemplars are alike in order to analyse findings across similar cases.

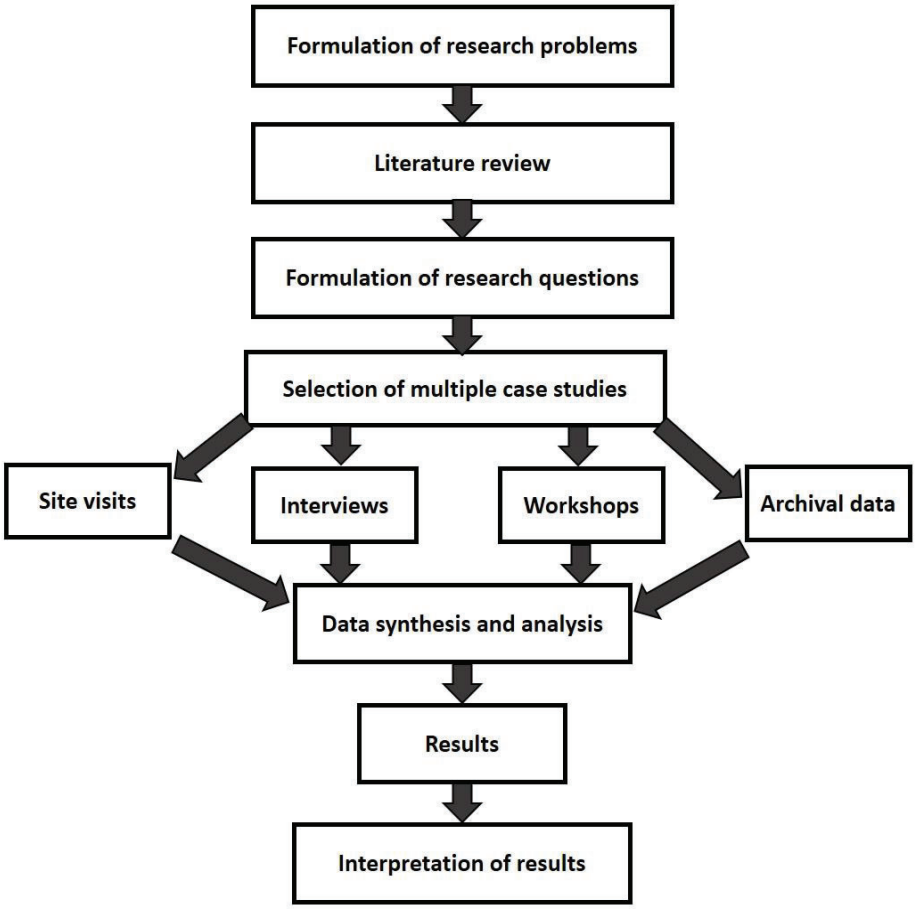


Figure 2.1 Multi-case study research design based on Yin (2018) and Francis (1999).

2.2 Data Sources

This research is based on primary and secondary data collected using a number of techniques and approaches. Empirical and critical analysis of the case studies gives background data to the five publications included in this thesis. A number of field studies were undertaken to collect primary data for the research project. Two overseas case studies are based in Singapore (Publication 2) and Vitoria-Gasteiz, Spain (Publications 2 and 3); one Australian case study is based in Melbourne (Publication 3), and five are based in Western Australia: White Gum Valley (Publication 4), Lathlain (Publication 4), York (Publication 5) and Jandakot (Publication 5).

The selection of biophilic projects analysed in Publications 1 and 3 was based on the open-sourced data available. The projects are based in Seoul (South Korea),

Birmingham (United Kingdom) and New York, Portland and Berkeley (United States).

2.2.1 Primary Data

The primary data collected for the selected case studies consist of:

Photographic documentation – Photographs were taken during the field trips. The photographic documentation of the case studies in Western Australia, to which access was relatively easy and inexpensive, were taken during different stages of the projects or time of the year. The photographic documentation provides information on the aesthetic, technical, design and performance aspects of the projects. It also documents changes occurring on-site and the landscaping components.

Information from site analyses (direct observations) and visual assessment – Data from site visits to constructed/in-progress projects is included. The site analysis undertaken by the researcher is based on her own subjective observations and interpretations guided by her professional work experience.

Notes from guided walks – Field trips were usually combined with oral presentations conducted by a guide who shared his/her knowledge of the project. Handwritten notes were taken during the guided walks and included in the case studies.

Recordings and transcripts of semi-formal interviews – Interviews were undertaken to deepen understanding of the processes and values behind the case study projects. The selection of interviewees was based on the ability, accessibility and availability of the actors and stakeholders involved in particular projects. The interviews had a semi-formal character, and they were recorded with permission from the interviewees. The recordings were transcribed, and the gathered data was analysed. The questionaries used in the interviews are attached in Appendices A and B.

2.2.2 Secondary Data

Open-source data available online, in print and via audio recordings were analysed and included in this thesis. The secondary data sources consist of:

Existing literature – Data concerning some of the projects were sourced from the peer-reviewed articles and books available online and in print.

Manuals and guidelines – Manuals regarding approaches, objectives and design applications were selected to inform this research project. Internet search engines were used to collect data since the manuals and guidelines were not scholarly literature but uploaded to websites or databases created by government or not-for-profit agencies.

Project documentation – Technical project documentation was sourced from the designers, government agencies and other stakeholders involved in the case study projects. The documents include the site analysis, the design proposal and detailed design. The engineering and hydrological assessments were also included and analysed. Project descriptions in professional online magazines were also examined. Professional design awards were used as sources of exemplary projects, for example, the American Society of Landscape Architects annual awards.

Brochures – Brochures issued by government agencies and private companies were included in the case-study data collection. The brochures explained the purpose, the process, the underpinning philosophy and values, the actors and other stakeholders involved in the conceptual design and execution of the case studies and examples of projects included in this thesis.

Archival materials – These included newspaper articles, public records, reports, audio recordings available online or in press, audio-visual recordings available on YouTube or Vimeo.

2.3 Selection of Case Studies

The selection criteria for the case studies were based on several factors (the rationale behind the case studies selection):

- They represent new approaches to urban landscape planning and design;
- BD and performance-—projects were assessed against biophilic elements, experiences and strategies developed by Kellert and Calabrese (Kellert & Calabrese, 2015);
- Availability of cost-benefit analysis;

- Availability of photographic documentation;
- Availability of scientific publications on the case study projects;
- Accessibility of the case study material published, critical articles and magazine publications by designers, scientists and other professionals;
- Whether the case study projects were public or private;
- Whether the actors and stakeholders were possible to identify and interview; and
- Accessibility of the sites.

The goal was to include examples showing significant increase in property value due to the development of a project presenting substantial biophilic qualities and experiences (Publication 1). The case studies were also selected to examine how biophilic elements of different scales can be used in urban biophilic regeneration initiatives (Publications 2, 3, 4 and 5).

2.4 Research Methods

A range of qualitative research methods were used in this research project: observational, historical (including literature review), behavioural, storytelling/anecdotal, interview, interpretation, analysis and evaluation. This section describes the methods employed for data collection and analysis. Table 2.1 outlines the methods used in each of the publications. Once the case studies were examined, the cross-case comparison was conducted, and is presented in Publications 3 and 4, to clarify key variables and identify how the key variables are patterned in each case.

Table 2.1 Research methods reported in the publications.

PUBLICATION	METHODS
1. "Biophilic urban regeneration: can biophilics be a land value capture mechanism?"	1. Literature review 2. Analysis and evaluation of the case studies: a) Analysis of publically accessible project documentation and reports b) Analysis of the newspaper articles
	1. Literature review

2. “Biophilic planning and Biophilic Urbanism.”	2. Analysis and evaluation of the case studies: a) Analysis of publically accessible project documentation and reports b) Site visits, photographic documentation c) Analysis of audio-visual recordings
3. “Biophilic Streets: a framework for creating multiple urban benefits.”	1. Literature review 2. Analysis and evaluation of the selected case studies: a) Analysis of urban street elements b) Site visits and analysis, photographic documentation c) Analysis of publically accessible project documentation and reports d) Semi-structured interview with planners
4. “Regenerating stormwater infrastructure into biophilic urban assets. Case studies of a sump garden and a sump park in Western Australia.”	1. Literature review 2. Analysis and evaluation of the selected case studies: a) Site visits and analysis, photographic documentation b) Analysis of publically accessible project documentation, reports c) A semi-structured interview d) Analysis of audio-visual recordings
5. “Indigenous Landscaping and Biophilic Urbanism: Case Studies in Noongar Six Seasons”	1. Literature review 2. Analysis of the selected case studies a) Analysis of newspaper articles, local government online press release and official informative brochures b) Site visits and analysis, photographic documentation c) Notes from guided walks d) Analysis of publically available audio recordings

2.5 Data Analysis

The analysis of the case studies aimed at extracting the type of data that helped to answer the research questions. Data was collected from many different sources using various methods as specified in Chapter 2. The qualitative data were analysed using the coding technique. Firstly, the reports were prepared for the case studies. Secondly, the case-specific themes were developed that gave background to the development of codes. The research questions, hypotheses, problem areas and key variables were considered when coding the data (Miles & Huberman, 1994). Further, the codes were used to develop analytical frameworks for the implementation strategies and concepts (Figure 1.2) which gave background to the five publications included in this thesis.

Besides the data from the case studies the reports included evidence from published literature that confirmed or disconfirmed the collected data.

2.6 Research Limitations

The nature of this research project (empirical inquiry) and the research questions determined the selections of the methodology and methods used.

Although a profound description and analysis of the selected case studies may have been desired, the researcher had limited resources and timeframe to undertake an exhausting study of every case and write long and very detailed reports. The amount of description, analysis, and summary material, that had to be collected, was a mutual decision between the researcher and the investigator. The researcher based her decision on answering the critical questions by Stake (Stake, 2005). The questions also present the case study limitations:

1. How much to make the report a story?

2. How much to compare with other cases?

3. How much to formalize generalizations or leave such generalizing to readers?

4. How much description of the researcher to include in the report?

5. Whether or not and how much to protect anonymity?

To avoid the issue of generalizability, several case studies were selected and analysed. The comparative analyses and results helped answer the research sub-questions and, ultimately, the main research question.

The limitations included the site visits to the selected projects that give rise to the case studies. Visiting the project sites was limited by the funds' availability, however, several sites were visited to document the findings on the ground.

Further limitations include the issue of obtaining the ethics clearance in order to conduct interviews with the indigenous persons. The research timeframe did not accommodate enough time needed to undergo the complex process. This was overcome by exploring and implementing other methods of including indigenous accounts in the research project.

3. Literature Review Summary

This chapter summarises the literature reviewed for this thesis. It includes the literature reviewed for each publication (Appendices C to G) and builds on the literature already examined in the earlier sections in Chapter 1. This narrative literature review considers extant literature and theories relevant to the research and situates the research within the field. It also provides the theoretical context for the main research question and sub-questions.

3.1 Biophilic Urbanism and Biophilic Urban Design (Publications 1 to 5)

The core theories underpinning this thesis, which are often used interchangeably in the literature, are biophilic urbanism (BU) and biophilic urban design (BUD). It is possible to distinguish between these terms if a scale criterion is applied. BU refers to city planning and developmental strategies, whereas biophilic urban design refers to particular projects, elements, strategies and designed forms within the urban realm. BU is the study of cities analysed through the lens of the biophilia hypothesis (Beatley, 2009, 2016b; Kellert, 2016b; Newman et al., 2017a). The theory of BU is based on the knowledge that humans have an innate need to affiliate with nature (E. O. Wilson, 1984), and that this need should be met on a daily basis (Beatley, 2011a) in order to maintain people's health and wellbeing.

A vast body of research into human health and wellbeing exists, that gives a strong basis for the development of BU theories and executive strategies (Beatley, 2016c; Kaplan & Kaplan, 1989; Ward Thompson et al., 2012). It has been well documented that nature and its analogues may assist with recovery from depression and other mental health disorders, that they can promote healing from diseases, strengthen attention restoration, aid recovery from stress or fatigue, and help to lower blood pressure and cortisol levels (Bowler et al., 2010b; Söderlund, 2019). For example, a widely disseminated research project carried out by Ulrich (1984) shows that there is a strong relationship between exposure to the natural environment, having a view of nature and natural analogues and the time needed for a patient to recover in hospital.

BU offers strategies for urban infrastructure to provide biophilic experiences to citizens (Beatley, 2016a; Beatley & Newman, 2013; Kellert, 2018; Kellert et al.,

2008; Kellert & Calabrese, 2015). These strategies also support and promote urban ecology and biodiversity and help to mitigate problems caused by changing climate (Newman et al., 2017b; Reeve et al., 2012). Newman et al. (Newman et al., 2017b) remind us that cities harbor a great deal of wildness, which sometimes is overlooked or underappreciated. However, due to those wild remnant areas, biophilic experiences can be provided without over-designing urban greenery.

An emerging body of research attempts to better understand what BU means in practice and what elements would bring biophilic experiences to the urban realm (Beatley, 2016b; Kellert et al., 2008; SBEnrc, 2012). However, the confusion over how to deliver BU at different scales remains (Desha et al., 2016; D. Jones et al., 2017; Littke, 2016). Timothy Beatley (2017) noticed that many projects executed in the urban realm have biophilic characteristics and provide biophilic experiences, although the terminology and strategies developed are rarely used.

The primary constraints to mainstreaming BU in Australia have been defined in a study led by the SBEnrc between 2010 and 2012. This research draws attention to the current research gap that needs attention to facilitate the delivery of BU (SBEnrc, 2012). The research conducted by Peter Newman and his team identified the enablers and disablers for biophilic projects (Table 3.1). The main obstacles to wider implementation of biophilic projects were found to be a lack of supportive legislation, economic issues, a lack of flagship examples and a cultural disconnection from nature, especially in urban settings.

Table 3.1 Factors that enable greening of urban environments (adopted from SBEnrc, 2012).

ENABLING FACTORS	DESCRIPTION
Policy	Supportive and adaptive policies and building standards driving innovation.
Government	Leadership in various levels of government and planning. Willingness to introduce supportive policy measures. Creative leadership responsive to community expectations rather than political cycles and traditional economics.

Social Pressures	Existing social and community groups' appreciation and pressure for BU. Availability of community leaders and change agents to assist in educating communities, establishing norms and supporting political processes. Existing appreciation of the benefits of nature.
Private Sector	The private sector can provide funding, leadership and "biophilic entrepreneurship" to drive the development of BU demonstration sites and general use within cities. This is further enabled through effective policies and incentives, and new economic models and valuation methods.
Demonstration	A growing number of demonstration sites showcasing the multiple benefits of BU and driving new norms in urban design.
Economics	Interest in new valuation techniques and metrics to enable the inclusion of traditional externalities in financial evaluations of building and urban design with BU, which in turn may enable access to finance for biophilic elements.
DISABLING FACTORS	**DESCRIPTION**
Lack of proof and qualification	Limited local research, information and economic data on biophilic elements prevents decision-makers from making justifiable decisions. Biophilic elements are vulnerable to financial pressures if the full economic and social value isn't demonstrable.
Existing policy and planning framework	A "silo effect" does not allow government to look holistically at a concept, and exacerbates split incentives. A lack of mandatory requirements makes BU a "beyond compliance" addition to building and planning. Existing regulations and planning requirements often do not support the inclusion of biophilic elements.
Cultural and social inertia	

	Cultural disconnection from the natural environment leads to ignorance of the benefits of experiences of nature and a lack of support for policies to increase urban nature.
Split incentives	Benefits and costs of BU are unequally borne by various government departments and between stakeholders (i.e., private organisations, government and society) such that the costs may be paid by a department, organisation or individual that does not recoup the full benefits.
Traditional economics	Traditional economic models that do not value externalities disempower decision-makers from including biophilic elements in urban and building design.

A study conducted by Coffey and colleagues (2020) points to the principles of ‘good governance’ as enablers to successful urban greening. The researchers analysed several case studies and highlighted the diversity of ways in which ‘good governance’ can be practiced. For example, transparency can be achieved through the openness of those involved in the processes, and legitimacy can be achieved by acceptance and association with institutes, government departments, and community groups. A focus on the principles of ‘good governance’ may encourage and support the involvement of diverse actors and organisations in urban greening initiatives.

In order to improve the uptake of BU, showcase examples of urban projects need to be well-documented, researched and disseminated to inform decision-makers, designers and also local communities on how to achieve biophilic objectives in real-world settings.

Cultural disconnection from the natural environment seems to be the challenge for mainstreaming BU around the world. In the case of Australia, deeply-rooted connections with natural environments seem to suffer from a lack of official support from local governments. While some positive, systematic changes have been recorded, the need for cultural reconnection with nature is not high on government agendas (Beatley & Newman, 2009; Desha et al., 2016; Newman, 2014).

Considering the existing research and literature on BU, and the knowledge gaps discussed above, it is clear that there exists an urgent need for theory to be translated into practice in a systematic way, and in a way that takes a whole-of-city approach rather than focusing on isolated projects and integrating separately considered human and ecological dimensions.

3.2 Land Value Capture (Publication 1)

Individual health and wellbeing are key determinants of quality of life, and are shaped by a diverse array of issues including urban density, transport and walkability, access to nature, food and culture. Nevertheless, they remain absent from the standard business models that inform the investments made by cities, and are often inadequately addressed in sustainability strategies.

BU considers how access to quality green spaces, and biophilic buildings and infrastructure, can support and enhance health and wellbeing. In order to provide people with adequate access to nature, cities should strategically plan and distribute biophilic spaces. However, traditional business models rarely take account of the health or economic benefits of biophilic spaces and elements. One of the financing models that could support the strategic investment in biophilic projects is land value capture (Cabanek & Newman, 2016). It has been shown that when this mechanism is applied, the redevelopment of an area can provide revenue to development authorities (McIntosh et al., 2014). The concept of land value capture first emerged in the United States as a way of funding urban regeneration (Newman, 2016). Urban regeneration involving green public spaces and urban infrastructure increases the economic value of the adjacent properties and land. Consequently, local land and sale taxes increase. Land value capture estimates these increases and uses it as a hypothecated fund to finance green space improvements (Cabanek & Newman, 2016).

3.3 Bioregional Planning (Publication 2)

Bioregions are areas that embrace local communities and surrounding landscapes, thereby providing those communities with food, fibre, water and space for recreation (Newman & Jennings, 2008). They also provide habitats for many species of fauna and flora. Bioregions are considered to be of sufficient size to manage whole ecosystems, including urban ecosystems (Miller, 2001).

Beatley (2011) proposed “green regions” as an approach to regional sustainability planning. He suggested mixing urban settlement with adjacent hinterlands and ecosystems to create compact and sustainable settlements. However, the challenge remains as to how green regions will connect the urbanised areas with the countryside. One possible solution lies in supporting bioregional planning to draw from BU to find solutions for urbanised and countryside areas.

Place-based approaches to bioregional planning are needed, and these could be achieved by adopting strategies from other sustainable planning and design approaches such as BU. Some societies have already approached complex socio-ecological problems by establishing place-based and regional solutions to support and enhance the health and wellbeing of residents (Pezzoli & Leiter, 2016).

In *The City in History*, Mumford (Mumford, 1961) pointed to the need to bring nature to cities in order to provide daily biophilic experiences to an urban population. He accused modernist urban planners and designers of following the ideas of modern progress, yet neglecting the relationship that humans have always had with the natural world. He charges modern urban planning with bringing sterility to the rural landscapes and death to the city.

3.4 Biodiversity, Ecosystem Services and Green Urban Infrastructure (Publications 1-5)

The European Parliament resolution (2016) on the mid-term review of the EU’s biodiversity strategy expressed concern about the continuing loss of biodiversity and called for reduced degradation and fragmentation. The resolution proposed that at least 15% of degraded ecosystems be restored by maintaining, enhancing and establishing new green infrastructure (European Parliament, 2016). Three years after the European Parliament issued the resolution, the UN report on biodiversity loss (2019) concluded that the world’s biodiversity was further declining at an unprecedented scale. A report prepared by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), warned that the current rate of global species extinction is ten hundred times higher than the average over the past 10 million years. The IPBES reported that out of 8 million animal and plant species up to 1 million are threatened with extinction, which will happen gradually during the next decades (IPBS, 2019).

Biodiversity is recognised as essential to humanities existence (Cardinale et al., 2012). According to the latest report by the IPCC (Masson-Delmotte et al., 2018), lowering global warming by 1.5°C, will require tools such as green urban infrastructure to mitigate the heat island effect in cities and to enhance biodiversity. The IPCC report also provides policymakers and practitioners with the information they need to make decisions toward mitigating climate change, while considering local context and the needs of populations. Global warming is likely to increase by 1.5°C between 2030 and 2052 if the current rate continues. If the rise of global temperature is not abated, the decline of biodiversity will continue at an accelerating rate (Masson-Delmotte et al., 2018).

3.4.1 Biodiversity and Urban Ecosystems

The relationships between urban biodiversity and urban ecosystems are often perceived as positive (Kabisch et al., 2016). In contrast, the review by Schwarz et al. (Schwarz et al., 2017) showed that the empirical evidence underpinning the relationship between urban biodiversity and ecosystems appears insufficient. Evidence is needed, for instance, to ascertain the role of particular species of fauna and flora in building healthy ecosystems. Furthermore, indigenous knowledge of local ecosystem structures and habitats may play a significant role in validating the positive relationship between local biodiversity and ecosystem services (Hunt et al., 2009; McKemey et al., 2020).

The networks and interdependencies between biodiversity and ecosystem services are only beginning to be understood (Newman & Jennings, 2008). The importance of ecosystem services in urban environments has been recognised for many years and their significance for cities should be expressed in urban planning policies. All urban activities depend on healthy ecosystem services and biodiversity, and form the basis for ecosystems that provide a large number of goods and services, as shown in Table 3.2.

Table 3.2 Ecosystem services and health needs (adopted from Newman and Jennings 2008).

ECOSYSTEM SERVICES			
PROVISIONING	**REGULATING**	**CULTURAL**	**SUPPORTING**
Goods provided by or produced by ecosystems: • Food • Fresh water • Fuelwood • Fibre • Biochemicals • Genetic resources	Benefits obtained from regulation of ecosystems processes: • Climate regulation • Disease control • Flood control • Detoxification	Nonmaterial benefits obtained from ecosystems: • Spiritual • Recreational • Aesthetic • Inspirational • Educational • Communal • Symbolic	Services that maintain the conditions for life on earth: • Soil formation • Nutrient cycling • Pollination • Maintenance of biological diversity
ECOSYSTEM HEALTH NEEDS			
• No net soil loss • Intact nutrient cycles • Absence of polluting gases or particles in the atmosphere • Absence of harmful concentrations of chemical compounds in water bodies and soil • Absence of harmful levels of ionising radiation			

3.4.2 Biodiversity and Human Health

Limited information is available to link biodiversity and human health (Sandifer et al., 2015). There is some evidence of positive indirect (Wall et al., 2015) and direct health effects of species-rich environments already exists in the scientific literature (Fuller et al., 2007). The studies led by Shwartz and colleagues (Shwartz et al., 2014) demonstrated a measurable positive association between species richness and aspects of psychological health and wellbeing. The authors suggest that heterogenic habitats may influence human health and self-perceived wellbeing.

3.4.3 Economic Value of Ecosystem Services

In terms of the economic value of urban ecosystem services, a study led by Costanza et al. (Costanza et al., 1997) estimated that ecosystem services

worldwide are worth on average USD33 trillion which is near twice the global GNP of USD18 trillion. The study drew attention to the possible economic losses the countries may suffer due to the exclusion of ecosystem services from their legislative acts. Although the ability of green infrastructure to deliver ecosystem services and biodiversity has been documented in many studies, cities still struggle to secure the resources and other capacities to implement appropriate agendas (Lovell & Taylor, 2013).

3.4.4 Green Urban Infrastructure

"Green urban infrastructure" is a term used to define strategic approaches to urban green space planning that focuses on network connectivity (Davies & Lafortezza, 2017). Green infrastructure replicates the ecosystem functions through natural vegetative systems, green methodologies and other nature-based technologies. It includes green areas or elements in private and public lands and properties (Vargas-Hernández & Zdunek-Wielgołaska, 2020). Several ecosystem services can be considered when evaluating urban green spaces: plant biodiversity, food production, microclimate control, soil infiltration, carbon sequestration, visual quality, recreation and social capital (Lovell & Taylor, 2013). The effect of green and urban infrastructure on human health and wellbeing should also be included in strategic urban infrastructure planning; however, this is not always the case.

Green infrastructure is also viewed as a tool for combatting the environmental consequences of climate change (Matthews et al., 2015; Norton et al., 2015). Many cities have taken important actions to mitigate the results of changing climate. In Paris, for example, government authorities decided to remove hard surfaces and turn them into green assets. In Milan, there is an ambitious plan to plant 3 million trees by 2030 (Pearce, 2019).

3.5 Culture, Ethnicity and Spirituality in the Urban Realm (Publication 5)

Culture, ethnicity and spirituality are, amongst many others, the characteristics of multicultural societies that need to be addressed when planning and designing urban environments (Carmona, 2019; Duxbury et al., 2016; Wansborough & Mageean, 2000; Yazdani & Lozanovska, 2014). From the public open spaces to a single building, multicultural societies should be given opportunities to express their cultural and ethnic values. Pedersen Zari (Pedersen Zari, 2019) pointed to the need

of cultural diversities and the differences between preferences of different groups of people to be effectively explored and integrated into BU and BD.

Designing biophilic experiences, which are culturally and ethnically sensitive, can be perceived as a new challenge for those design professionals who wish to follow the BU strategies. Buijs et al. (Buijs et al., 2009) argue that public places are essential to a community's success and this has been recognised by social scientists, urban planners, and community organisers. The neighbourhoods with vibrant public places are characterised by greater social capital.

Many studies have been conducted to understand the patterns of use of public places by people of different ethnic and cultural backgrounds (Cruz et al., 2018; Selin, 2003; Talen, 2008; Taylor, 2018). For example, Low et al. (Low et al., 2005) argues that the most successful public spaces are those where cultural differences are valued and expressed through design which nurtures many different preferences, where individual cultures are celebrated. Courtney Knapp (Knapp, 2008) from Project for Public Spaces recalls the Ethnicity Theory which explains that "the varying patterns of use in public spaces is the result of differences in cultural values attached to a space or activity, not merely differences in access".

One of the factors contributing to the creation of culturally and ethnically- sensitive urban spaces is the recognition given to indigenous ecologies. Birkeland (Birkeland, 2012) suggests that indigenous ecologies can serve as a guide for retrofitting cities. If embraced, this could help BU to develop design strategies and solutions addressing the needs and preferences of multicultural urban societies.

Cultural diversity and the differences between the needs of various groups and communities remain important factors of BD that can determine the success of biophilic urban interventions. Urban planners and designers should respond to an understanding of people's innate connection to the living world (Beatley, 2009; Pedersen Zari, 2019). For example, a notion of experience through time and the seasons may influence an individual understanding of biophilic places. To ensure adequate psychological and ecological benefits, the needs of different ethnic, cultural, indigenous, or immigrant groups need to be recognised and addressed by designers.

3.6 Conclusions

The following is a summary of the literature review, which identifies the knowledge gaps that have led to the main research question and the sub-questions of this thesis.

The vast body of literature on BU and design focuses predominantly on its theoretical aspects. The elements, strategies and experiences of BU have been distilled and documented, and form some guidelines for designers, urban planners and other various stakeholders.

No literature was found on examples of delivery processes that could become a baseline for biophilic urban projects. Most studies explained current theories, historical accounts, opportunities and constraints, but failed to present a framework for the delivery of biophilic urban projects.

There have been some attempts to design and deliver urban projects based on the principles and experiences of BU; although no framework has been established that could inform designers and planners of tested and proven pathways to the successful execution of biophilic projects. The difficulties with finding suitable and vacant space for quality biophilic projects in the urban realm remain significant. The most common public open spaces in cities are streets and their potential to become biophilic places is yet to be fully examined. Some examples of urban infrastructure have been found to comply with the principles of BU, however, and have been presented as important case studies in academic and professional literature. Some examples include the High Line in New York (Beatley, 2011a; Reeve et al., 2013) or Gardens by the Bay in Singapore (Beatley, 2016b; Newman, 2014).

The economic benefits of BU have been presented through the analysis of individual projects and initiatives. In many case studies, the applied research methodologies are place-specific and aim to estimate the hedonic value of biophilic projects; that is, how much one is willing to pay.

The cultural aspects of urban green infrastructures are rarely considered in urban development projects, and design initiatives often fail to meet the cultural and spiritual needs of multicultural urban communities. Urban planners and designers frequently try to impose current trends and fashions and disregard local, and

possibly ancient, knowledge and heritage. Style, materials and design criteria bow to the pressure of globalisation and become universally adopted by designers in different countries in an attempt to achieve similar results across different climatic, environmental, social and bioregional conditions. This leads to the implementation of infrastructural designs that are out of place or disconnected from local heritage, history and community needs. Historical aspects, and local cultural and indigenous knowledge should be carefully considered in the design process of urban green infrastructure.

4. Publication Summaries

This chapter presents a brief summary of each publication submitted as part of this thesis. It shows the logical progression between them and the results of each. The full publications have been reproduced in Appendices C to G. Each publication answers a sub-question of the thesis.

4.1 Publication 1: "Biophilic urban regeneration: can biophilics be a land value capture mechanism?"

Status: Published in a peer reviewed conference proceedings *Sustainable Development and Planning* (Appendix C)

Cabanek, A. & Newman, P. (2016). Biophilic urban regeneration: can biophilics be a land value capture mechanism? In C.A. Brebbia, S.S. Zubir & A.S. Hassan (Eds.), *WIT Transactions on Ecology and the Environment. Sustainable Development and Planning* (pp. 65-78). Doi: 10.2495/SDP160061

This publication addresses sub-question 1: *How can BU be funded?*

4.1.1 Abstract

The selected case studies are analysed through the lens of land value capture as a theoretical funding mechanism for biophilic urban projects. This paper suggests a possible funding mechanism to enable BU to be mainstreamed as a part of urban regeneration. It examines whether land value capture could be used to fund mainstreaming of biophilic urban projects.

4.1.2 Research Methodology

Case study methodology was used to conduct this research. Three case studies were selected to investigate the relationship between property value and regenerated urban infrastructure to validate the initial hypothesis that biophilic structures and elements of different scales enable urban regeneration to become financially attractive to private and public investors. A hedonic pricing methodology is commonly used in urban studies to estimate the impact of green urban assets on real estate value. The hedonic price model is used to evaluate willingness to pay for

the given difference in proximity of properties to environmental amenities (Liebelt et al., 2018).

4.1.3 Land Value Capture

The concept of land value capture first emerged in the United States as a way of funding urban regeneration (Newman, 2016). Urban regeneration involving green public spaces and urban infrastructure increases the economic value of the adjacent properties and land. In consequence, local land and sale taxes increase. Land value capture proposes to estimate these increases and use it as a hypothecated fund to finance green space improvements.

4.1.4 Value Capture and Biophilic Urbanism

This publication is based on the analysis of three case studies: Cheonggyecheon Stream Restoration project in Seoul, South Korea; the Canalside regeneration project in Birmingham, United Kingdom; and the High Line Park in New York, the United States. In the first two case studies, the researchers examined the land value capture from the regeneration of traditional green and blue urban infrastructure. Analysis of the third case study showed how innovative biophilic structures, such as elevated urban green ways and parks, contribute to the increase of land and property values. The case studies reveal how the mechanism of land value capture could be applied to finance biophilic projects.

The Cheonggyecheon Stream Restoration Project in Seoul is a flagship example of urban regeneration that included revitalisation of blue urban infrastructure. The underground waterways were redirected to create a new streambed with landscaped banks and restored ecologies (CABE, 2011). The regenerative strategies provided biophilic effects as well as significant economic benefits for adjacent land and properties. The residents gained new recreational space, the stream was revived, and its ecology restored and increased by 639% between 2003 and 2008 (Landscape Architecture Foundation, n.d.). The reported economic gains feature a significant increase in the land value by 30 to 50% for properties within 50 metres of the project, which was double the increases in other parts of Seoul. The overall cost of the project was USD380 million, and the regeneration has served as a catalyst for an estimated KRW22 trillion (USD1.98 billion) worth of capital investment in the Cheonggyecheon redevelopment area. The project is an example of successful urban regeneration in which green and blue infrastructure became key

incentives for economic development (Landscape Architecture Foundation, n.d.; Lee & Anderson, 2013; Yeon Hwang, 2004).

In 2014, Birmingham, in the United Kingdom, became a member of the Biophilic Cities Network and committed to the city-wide regeneration of rivers, stream and canals to restore their ecosystems, regenerate and develop adjacent land and properties, and provide a grid of pathways and trails to support local tourism. According to the study led by GHK in 2009, the net impact of the City Centre canalside development on property values was between GBP25.7 and GBP57.1 million (Gore et al., 2013). The canalside regeneration is an ongoing initiative and includes a number of projects initiated by the local council as well as private investors and stakeholders.

The economic benefits of canalside properties can see an increase in value. The regeneration encourages the reuse of land and buildings. The 2011 IWAC report, 'Value of the Inland Waterways', highlighted the significant benefits that navigable waterways in the UK can bring (Hazenberg & Bajwa-Patel, 2014). It was estimated that the baseline benefits of inland waterways were between GBP109,000 and GBP730,000 per kilometre.

One of the most successful urban regeneration projects, featuring many aspects of BD, is the High Line, an elevated urban park in Manhattan, New York, in the United States. The High Line was built in three phases between 2006 and 2014 on a neglected freight rail lane. The project was developed and promoted as an economic regeneration of an industrial area and has become one of the major tourist attractions in New York (Ascher & Uffer, 2015; Beatley, 2011a). The High Line project significantly lifted the value of surrounding properties and stimulated the commercial and residential property market resulting in an estimated USD4 million in private investment (Beatley, 2011a). Friends of the High Line, a not-for-profit organisation established to lead the project, studied the potential economic gains for the freight line area. These studies projected how incremental tax revenues created by higher real estate values around the park would outweigh the costs. The organisation managed to raise USD300 million from private investors to finance the completion of the project and the ongoing maintenance (Ascher & Uffer, 2015) on the basis that it would improve the value of their properties. According to Levere (Levere, 2014), after partial completion of the project the impact on property sales

was estimated at a USD100 million increase in property taxes that the city gained in 2010.

Factors that led to the successful execution of the project were, according to Ascher and Uffer (Ascher & Uffer, 2015), the marketing campaign carried by The Friends of the High Line and their celebrity supporters; political and federal government support; the public-private partnership between Friends of the High Line and government; and the re-zoning and new regulations that allowed potential development to the area.

The High Line initiative shows an alternative way of funding green infrastructure projects, using projected tax revenues and other financial benefits to activate a project. Similar elevated greenways and linear parks have been planned for Chicago, Philadelphia, Atlanta and Rotterdam (Triman, 2013), proving that private and public investors are starting to recognise the value of urban regeneration using biophilics.

4.1.5 Conclusions

In this paper, the authors propose implementing a mechanism of land value capture as a way of funding biophilic projects by private and public investors. The proposed land value capture mechanism has been successfully used in the United States, Canada, Japan and Hong Kong. The concept is founded on the principle that land value is determined by its intrinsic value plus any private investment that is enabled because of investment in infrastructure, economic development and population growth. From the analysis of the selected case studies, it has been shown that the increase in land value could be generated through a strategic design of public amenities using the principles of BU. A local government can gain extra taxation revenues as a result of new development, without raising existing rates. These revenues can be forecast and included into future budgets as a means of paying for biophilic urban infrastructure costs up front.

Urban greenery has been shown to have the potential to uplift the value of land and adjacent properties. Therefore, it is likely that BD principles informing strategic urban design may further increase this value. Furthermore, this increase in land value can be used to attract private and public investors to deliver new businesses in the area. New investments help to create vibrant neighbourhoods, indirectly lifting

the value of all properties nearby. The results suggest that a government mechanism of land value capture can be used to mainstream biophilic projects in urban policy.

4.2 Publication 2: “Bioregional planning and biophilic urbanism”

Status: Published in a peer reviewed book (Appendix D)

Newman P. & **Cabanek A.** (2020) Bioregional Planning and Biophilic Urbanism. In D. Fanfani & A. Matarán Ruiz (Eds.), *Bioregional Planning and Design: Volume I*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-45870-6_7

This publication addresses the second sub-question: *How can bioregional planning incorporate BU?*

4.2.1 Introduction

Bioregions are large areas of geophysical patterns characterised by landscape-scale natural features. They emerge from complex environmental processes. A bioregion is defined by natural borders, not by administrative borders (Thayer 1997, 2009; Fanfani 2009, 2013), and is responsible for providing ecosystem services—food, fuel, water, fibre, waste management and ecological services—critical for the existence of cities.

BU is an approach to urban planning and design based on the knowledge that humans have a need to affiliate with nature that should be met in their daily lives (Beatley, 2011a; Kellert, 2016b; Kellert et al., 2008). The special niche of BU focuses not only on applying greenery onto building façades and roofs, but also inside buildings (Kellert, 2018; Kellert & Calabrese, 2015; Newman, 2014). Although bioregionalism and BU are related, the link between them is not always made. BU is a new movement in urban planning and design which tries to re-establish the integration between cities and bioregions (Hes & Du Plessis, 2015; Newman & Jennings, 2008). The main objective of this study was to demonstrate how cities can develop their bioregional strategies from BU and design strategies.

Cities continue consuming and eroding natural environments and resources by expanding their boundaries and developing on greenfields. Recently, however,

cities have been pressured to go beyond merely minimising their impact on bioregions to regenerating bioregional natural systems, and many urban development projects do go beyond just limiting their impact (Newman et al., 2017b). Green infrastructure is favoured over grey infrastructure to achieve similar results; for example, green spaces are used to manage stormwater (Prudencio & Null, 2018; Wong & Breen, 1998). The centuries of damage done by cities to their bioregions can be restored, and urban nature regenerated. Incorporating the strategies of BU into bioregional planning offers a way forward.

4.2.2 Green Roofs and Green Walls

A wide range of methods for integrating nature into the built environment have been developed with the potential of linking biophilic structures into bioregional regenerative outcomes. Green roofs and green façades have a strong presence in many cities around the globe (Bowler et al., 2010a; Dunnett & Kingsbury, 2008), due to the introduction of local sustainability policies (Söderlund, 2019).

4.2.3 Linking Bioregionalism and Biophilic Urbanism

In order for BU to assist with the bioregional agenda, it needs to show how urban biophilic features (e.g., green walls and roofs) can improve bioregional outcomes. Three links between bioregionalism and BU are proposed as part of this research: ecosystem services, biodiversity and sense of place (Figure 4.1).

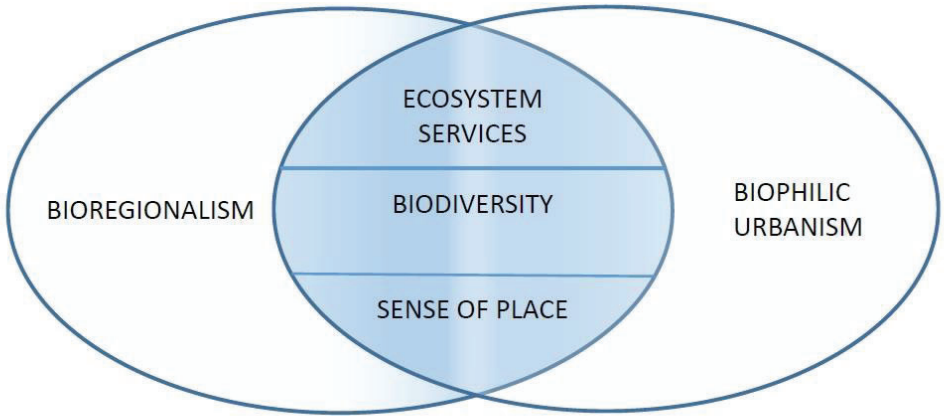


Figure 4.1 The three links between bioregionalism and BU. Credit: Author

Biophilic urban structures can provide ecosystem services, which can assist bioregional ecosystems and support watershed management, waste management and the provision of water, food and fibre. These structures are also known for enhancing energy production when combined with solar panels, and reducing energy consumption through the insulation green covers provide (Hui & Yan, 2016). Green roofs, green walls, rain gardens, bioswales and other green structures can retain and cleanse both rainwater and air of pollutants. Local food production in rooftop gardens and vertical gardens is a widespread practice which, besides food, provides many biophilic experiences to local residents and visitors. The two case studies in Singapore and Vitoria-Gasteiz, Spain, present design and policy solutions for linking BU and bioregional planning.

4.2.4 Biodiversity

The protection and enhancement of global biodiversity is an obvious priority for progressive and sustainable cities. Global studies show that some cities feature high levels of biodiversity in their urban landscapes (Elmqvist & Mcdonald, 2013). Biophilic structures can help with biodiversity enhancement (Beatley, 2016b; Lundholm, 2015). In Switzerland, research on green roofs focused on estimating levels of biodiversity. In France, many “wild-colonised” green roofs are composed of native species. The key to enabling biodiversity links between biophilic structures and a bioregion is the selection of plant species and construction of habitats.

4.2.5 Sense of Place

Cities develop their own place-oriented strategies to achieve higher levels of sustainability and resilience by designing their built environment to become more sensitive to local, regional and planetary environments (Beatley & Newman, 2013) Newman and Jennings (Newman & Jennings, 2008) developed strategies which enable cities to foster a sense of place. One of the strategies they propose is intended to connect the urban form to the bioregion by designing biophilic structures with ecosystems that reflect bioregional ecosystems. Local authorities may include biophilic tools and strategies into local policies to enable new urban biophilic projects. An example of a city which employed this strategy is Vitoria-Gasteiz in Spain. A number of policies enable linking biophilic projects and structures to regional ecosystems. In the case of Singapore, BU has been mainstreamed into the town planning system. Singapore’s BU demonstrates how a dense city not only can

regenerate natural systems, but create many more using the principles of BU (Newman, 2014).

4.2.6 Conclusions

Bioregional planning and BU share many similarities in environmental planning and design. Bioregionalism needs to bring its insights and science into city policies to inform design of biophilic structures, and BU needs to extend its science and insights through the natural corridors and out to the bioregions. The two case studies of Singapore and Vitoria-Gasteiz demonstrated how this can be achieved.

4.3 Publication 3: "Biophilic streets: a design framework for creating multiple urban benefits"

Status: Published in a peer reviewed journal (Appendix E)

Cabanek, A., Zingoni de Baro, M.E. & Newman, P. (2020). Biophilic streets: a design framework for creating multiple urban benefits. *Sustainable Earth*, 3(7), https://doi.org/10.1186/s42055-020-00027-0

This publication addresses the third sub-question: *How can urban transport planning of streets incorporate BU?*

4.3.1 Background

Urban streets provide space for transportation as well as public life (Gehl, 2010; Jacobs, 1961; Kostof, 1999; Matan & Newman, 2016; Mumford, 1961). The work of Jane Jacobs and Jan Gehl explored the functioning of urban streets and highlighted their important social and economic values beyond mobility and transportation. Due to the emergence of new typologies in urban design and their objectives, the ecological functions of streets gained attention from urban design and planning authorities. For example, rain gardens have been installed in many cities around the world as a solution to stormwater management and for the enhancement of urban biodiversity (Bain et al., 2012; Church, 2015). Such ecological functions are amongst the objectives of BU. The main focus of BU is increasing human interactions with nature, but this depends on having a healthy, biodiverse and functioning urban green infrastructure. Ecological features, as well as connectivity

between different types of urban green infrastructure, are crucial for the healthy and efficient functioning of ecosystems (Beatley, 2011a, 2016b; Kellert et al., 2008).

The work of Wilson, Kellert, Beatley and others has helped to advance studies on the biophilia effect, BU and the means of applying these in urban environments (Beatley, 2011a; Kellert et al., 2008; E. O. Wilson, 1984). Another author, Salingaros (Salingaros, 2010), suggested that there are specific geometrical properties in nature that have shown positive influence on human psychological and mental health. As noted above, he called this influence the biophilic effect. This paper analyses different design techniques and features of urban streets that could provide a biophilic effect. It uses the science behind the idea of the biophilic effect, the environmental, socio-economic and psychological benefits of biophilia and biophilic elements and attributes proposed by Kellert and Calabrese (Kellert & Calabrese, 2015), and applies them to urban streets to develop a theoretically and practice-informed design framework. It is hoped that this framework will assist urban planners, designers and other decision-makers in more effective planning and delivery of BU.

4.3.2 The Streets

Since the development of the first cities, streets have always been their most accessible and common public spaces, the centres of social life and many activities, and spaces for business, mobility and commuting. Modern regulatory frameworks for street design are engineering-focused; their concern is mostly on efficiency, safety and a rapid conveyance of traffic. This has contributed to the detachment between people and nature, its ecologies and ecosystems (Steiner et al., 2016). The modernist guidelines for urban street design were challenged by Jane Jacobs (Jacobs, 1961) who highlighted the omission of diverse social and economic networks from new urban street standards and functions. Jan Gehl (Gehl, 2011) developed a framework for urban street design that aimed to bring back and facilitate close social interactions and other benefits. His framework also aimed to reduce the use of private vehicles, and promoted walkability and public transportation to reduce the environmental impact of cities. By applying the framework, streets could become more liveable, friendly and safe places for everyday activities.

Streets are where people tend to spend the most time commuting and, occasionally, shopping. Therefore, the available space within a street's median, when designed with biophilic principles in mind, could facilitate physical activities, improve wellbeing and foster urban natural systems. To be able to foster connections between humans and urban nature, urban planners would need to identify spaces for introducing biophilic experiences. Considering the fact that urban streets comprise 80% of urban open spaces, it becomes important to look for opportunities to transform these transportation corridors into places where urban nature could thrive.

4.3.3 Developing the Framework

Development of the framework for biophilic street design was based on people's experiences of biophilic places and the street design functions and objectives (Table 6). The characteristics of a biophilic street were compiled and divided into six categories to reflect the functions of streets: traffic planning, energy management, stormwater management, biodiversity management, street furniture, activities and education. The framework is then applied to four selected examples of street revitalisation.

Table 4.1 Framework for biophilic streets design. Credit: Authors.

FRAMEWORK FUNCTIONS AND OBJECTIVES		BIOPHILIC DESIGN ELEMENTS		
DESIGN FUNCTIONS	**SELECTED DESIGN OBJECTIVES**	**BUILDING FAÇADES**	**ROAD RESERVES**	**POCKET PARKS**
Traffic Planning	Creating space for BDs by redesigning traffic lanes, traffic calming schemes, reducing lanes, prioritising pedestrians, transit and bicycle lanes and providing pocket parks.	Integrating vertical greenery into and onto buildings, such as green walls, green balconies, planter boxes; green roofs.	Integrating native gardens, edible gardens, nature playgrounds and other biophilic features on verges, median strips, round-about, "ramblas," green bridges and flyovers, buffers between roads and cycling and/or pedestrian paths.	Integrating native gardens, edible gardens, nature playgrounds, water features, habitats for birds, insects and small animals, street furniture and amenities in median strips, ramblas, roundabouts, vacant lots, plazas, spaces between buildings.

Energy Management	Cooling streets for walking, reducing urban heat island effect and saving energy through insulating buildings.	Green walls, roofs, and balconies to provide thermal insulation; cooling (evapo-transpiration); air purification; relaxation. Combination of green roofs and solar panels.	Tree canopies that shade pedestrians as well as shading buildings.	Pocket parks can be built around all three energy management ideas.
Stormwater Management	Water retention, purification, and reuse.	Green walls, green roofs, green balconies that filter rain.	Street trees, tree pits, linear gardens, bioswales, rain gardens, daylighted streams.	Rainwater tanks, pervious pavements.
Biodiversity Management	Biodiversity enhancement, restoration, creation of various habitat sizes and types that enable regeneration of urban ecosystems.	Green walls, green roofs, green balconies.	Street trees, tree pits, linear gardens, bioswales, rain gardens, daylighting streams.	Plant beds, potted shrubs and trees, green walls, water features.
Street Furniture	Incorporating biophilics into every small function in the street, including seats, signs, bus shelters and street art.	Street art combined with filtration systems to conduct runoff from green roofs.	Parklets Green roofs on top of bus and transit shelters. Street art combined with filtration systems. 'City trees' installation to facilitate air purification. Vertical pallet edible gardens.	Urban furniture to support natural systems. Green roofs on top of bus and transit shelters. Street art combined with filtration systems. 'City trees' installation to facilitate air purification. Vertical pallet edible gardens.
Activity and Education	Enabling both activity that uses street functions and understanding of how nature fits into the city as well as the social and cultural value of the street.	Tourist and visitor information in streets explaining biophilic façades.	Integrated street furniture with green features explained. Educational features – information plates, educational stations; activity points (smart play equipment,	Integrated street furniture with green features explained. Educational features – information plates, educational stations; activity points (smart play equipment,

			art installations, water features).	art installations, water features).

4.3.4 Analysis of the Streets

Four examples of street revitalisation were investigated using the framework provide above as an analytical lens. Each revitalisation project used different tools and approaches to formulate design solutions, which, directly and indirectly, achieved a biophilic effect. The analysis showed how modern urban streets can be designed and built in a way that provides people with opportunities to interact with nature that is biodiverse and thriving.

The most spectacular biophilic street elements were built along Gasteiz-Hiribidea Street in Vitoria-Gasteiz, Spain, where the living stream was revitalised and green walls and roofs covered the adjacent Palacio de Europa building. These biophilic constructions aimed to enhance biodiversity along the street and at the same time educate pedestrians about the native flora and fauna of the local bioregion. The greenery also helped to reduce the heat island effect. The green walls and roofs thermally insulated the building, thereby reducing the energy required for cooling and heating.

Another example of a street renewal project comes from Downtown Berkeley. This initiative aimed at providing the usual functions of the streets but also enhancing social activities and promoting ecological awareness. A number of sustainability goals were reached, and the outcomes featured many biophilic attributes and experiences. Consultations involving local community representatives revealed that the provision of space for social activities was a key objective. Landscaped buffers between pedestrians and traffic, temporary parklets, narrowing traffic lanes and using the space to plant trees, installing sculptures and equipment for interactive play are only some examples of biophilic interventions which fulfilled objectives voiced by the local community. The revitalisation of the Downtown delivered many other biophilic solutions and created attractive, walkable and restorative public spaces (City of Berkeley, 2012).

One of the first streets undergoing a green transformation in Portland, Oregon, in the United States was SW Montgomery Street. The city council adopted strategies to activate the neighbourhood, build community culture, enhance the pedestrian

experience and showcase their sustainability agenda. The new street design concept focused on creating a new place-making model for other streetscapes in the city. Proposed biophilic structures, such as stormwater planters and swales, became educational amenities for local communities. Local students were encouraged to monitor the performance of the green infrastructure installed along the street. The green walls and roofs were proposed for installation on adjacent buildings to improve ecological conditions and direct stormwater to raingardens and swales. The revitalised street maintains its original function as a transportation corridor, but also provides space for public interactions and ecological functions (Rottle & Yocom, 2011).

The last project examined is in Melbourne. In 2015, the local council initiated the revitalisation of four lanes: Coromandel Place, Guildford Lane, Katherine Place and Meyers Place. The main objective of this pilot project was to showcase sustainable solutions in street design and enhance liveability in the city centre. Four street typologies were established and tested: forest, park, farm lane and a vertical garden lane. Biophilic elements such as window boxes, planter boxes, hanging baskets, miniature raingardens and green walls were designed to provide habitat for wildlife, filter pollution and stormwater, and slow local traffic. A number of social and economic benefits were projected by the council; specifically, walkability and engagement in social activities. These lanes have become further tourist attractions amongst the already-famous and celebrated Melbourne lanes.

4.3.5 Conclusions

The revitalisation programs of streets, lanes and alleys have emerged in many cities around the world. Although programs differ in approach and objectives, there is increasing application of biophilic elements and strategies that enable additional objectives around the provision of ecosystem services, aesthetic elements and opportunities for social life. Streets are usually overlooked when biophilic spaces are sought, although they have the potential to deliver the most effective and accessible biophilic experiences. Thus, a biophilic street development has the potential to benefit the highest numbers of urban residents. Evidence on what types of street interventions are most effective is needed to guarantee that investment in nature-based solutions can cost-effectively address the public health challenges in urbanised areas.

4.4 Publication 4: “Regenerating stormwater infrastructure into biophilic urban assets. Case studies of a sump garden and a sump park in Western Australia“

Status: Published in a peer reviewed journal (Appendix F).

Cabanek, A., Zingoni de Baro, M. E., Byrne, J., & Newman, P. (2021). Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia. *Sustainability*, *13*(10), 5461. http://dx.doi.org/10.3390/su13105461

This publication addresses sub-question four: *How can urban stormwater engineering incorporate BU?*

4.4.1 Background

Urban life is becoming negatively affected by rising temperatures, air pollution and more frequent extreme weather events ((Masson-Delmotte et al., 2018; The Nature Conservancy, 2018). These issues affect humans as well as natural environments in urbanised areas and demand attention in order to enhance biodiversity and urban ecosystem services. BU, as a design and planning strategy, is known to enhance human health and wellbeing, and reveal the positive effects of human interaction with biota in urban environments (Beatley, 2011a, 2016a; Kellert et al., 2008; Newman, 2014). In this paper a biophilic approach to natural systems in urban areas is applied to the practice of urban stormwater management.

4.4.2 The Sumps

In Western Australia, a sump is a local name for a stormwater infiltration-basin where the runoff is retained and allowed to infiltrate into an unconfined superficial aquifer. They are typically designed as fenced-off basins with steep edges and no public access (Grose & Hedgcock, 2006). They differ from contemporary infiltration basins which may be better integrated into the surrounding landscape and perform bio-infiltration functions (Department of Water and Environmental Regulations, 2007). Although sumps perform their designated function as part of urban stormwater infrastructure, they have not been considered or valued for their potential socio-ecological role.

4.4.3 Materials and Methods

Using the principles and theories of BU and regenerative design, the paper analyses and discusses two local case studies: the “WGV sump park” in White Gum Valley and the “Green Swing sump garden” in Lathlain, Western Australia. The case study method of qualitative enquiry (Yin, 2009) was used to define the emerging framework for mainstreaming biophilic regeneration of stormwater infiltration basins. The framework aims to investigate how the actors, drivers, constraints, strategies, and values motivating the stakeholders, could inform the reinvention of the sumps (Figure 4.2). The data sources include document analysis, site visits, photographic documentation and semi-formal interviews.

The results for each case study are first presented to show their ability to reach stormwater biodiversity and livability goals, and then analysed to show how they could be mainstreamed.

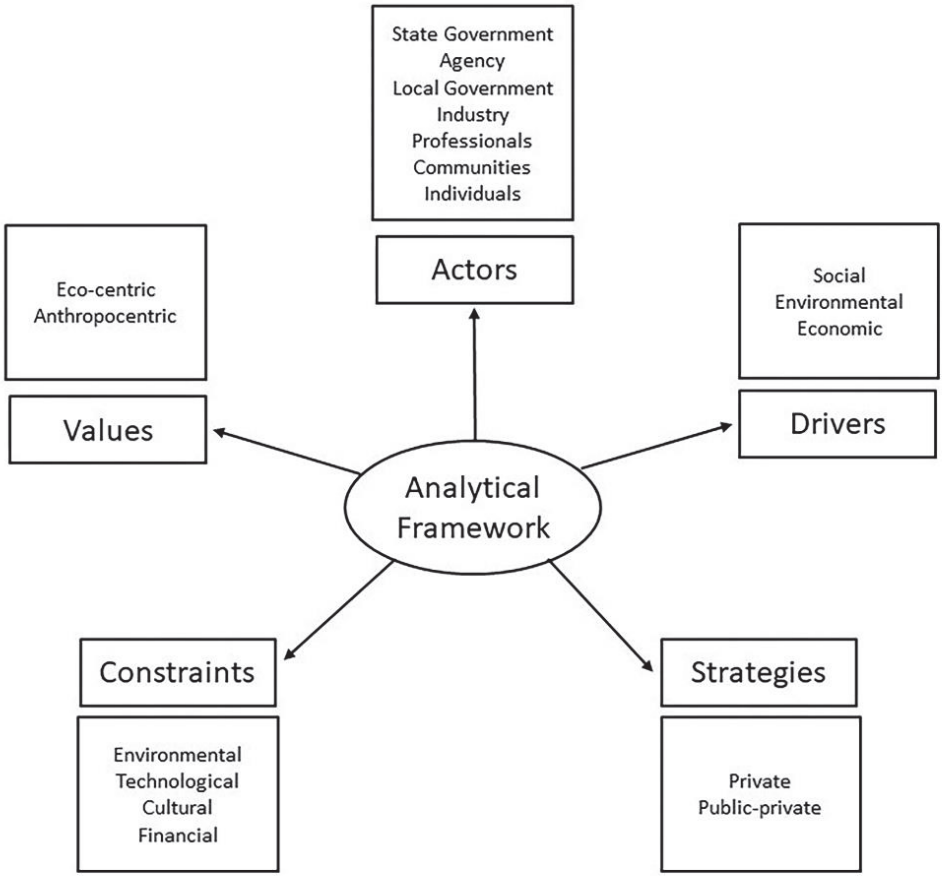


Figure 4.2 Analytical framework using qualitative inquiry. Credit: Authors.

4.4.4 Analysis of the Case Studies

4.4.4.1 White Gum Valley Sump Park

The White Gum Valley (WGV) residential development in Fremantle, Western Australia, demonstrates an innovative approach to urban infill using the One Planter Living framework to achieve zero carbon outcomes (Bioregional, 2015; Wiktorowicz et al., 2018). Adjacent to the residential site was a fenced sump owned and managed by the local government. The developer and other stakeholders decided that the sump had potential to become a green amenity for the neighborhood and it was integrated into the development's planning (Byrne et al., 2018; CRC for Water Sensitive Cities, 2017; Landcorp, 2018). The revitalisation of the sump aimed to connect this underutilised space into a publicly accessible landscape. The engineering and landscape design ensured that the site retained its original function as stormwater infrastructure, but increased its canopy and biodiversity, and provided recreational facilities (Byrne, 2018; Byrne et al., 2018). In terms of hydraulic performance, the sump successfully manages the stormwater. In terms of One Planet Living principles, the sump created new habitats and contributed to an increase in biodiversity.

4.4.4.2 Green Swing Sump Garden

The Green Swing is the name of a group of "citizen developers" who collaboratively developed a residential site in Lathlian, Victoria Park, Western Australia. The main objective of this development was to find a sustainable way of building homes, and in this case, it included two townhouses and two apartments (Byrne et al., 2018; Stockmann, 2018). The group also anticipated that the sump garden would help the local neighbours get to know each other while looking after the natural environment. The decision to develop the site at 96 Ruthland Avenue was influenced by the presence of an adjacent sump, which the group considered an opportunity for transformation into a productive and recreational space. The proposal to convert the sump into a community garden was approved by the local council. In collaboration with a local community garden association, the group developed a model for a biophilic regeneration of underutilised urban space. After the transformation, the sump garden upheld its original function as a stormwater basin (Byrne, 2017; Byrne et al., 2018; Stockmann, 2018).

4.4.5 Applying the Framework to the Case Studies

The results of the analysis highlight commonalities and disparities between both cases. The objective of applying the framework was to determine whether the regeneration of modernist sumps into regenerative urban green assets can contribute to creating sustainable communities and inform policies about the potential for replication and mainstreaming.

The projects were initiated and constructed within 5 years of each other (2010 and 2015). Due to the differences in scale and scope, the cases involved a diversity of actors. The social and environmental benefits were crucial for the group behind the Green Swing project. The garden provided space for inspiration and collaboration, helping to build the community. One of the main objectives for the stakeholders of the WGV sump park project was to demonstrate an innovative way of redeveloping an underutilised urban infrastructure to deliver additional ecological, social and economic benefits. In both projects, addressing the environmental issues was considered crucial.

The various strategies used to deliver the projects were a response to the objectives and scale of each development. In the case of the Green Swing sump garden, the strategy for the biophilic regeneration of the sump was to increase urban green spaces and gain additional productive and recreational space. Given the more complex and larger scale of the WGV sump, the project required a stronger strategy with professional input. A public-private partnership was developed to create an innovation through demonstration model.

Similar issues emerged for both cases in terms of constraints. The concerns at local government level had to be addressed in order to obtain relevant approvals. Health and safety, hydrology and drainage requirements were the main issues arising. The challenges identified as the most difficult to overcome were related to legal status, path dependency and leadership.

The values supporting the decisions made show that the similarities were related to social, ecological and economic aspects of the developments. In both cases, the personal values comprised community building, sustainable urban living, innovation and place-making. The principles of sustainable development highlighted in the One Planet Living program shared the values of the stakeholders involved in the revitalisation efforts of the WGV sump. For the developers of the Green Swing sump

garden, the main values were community building and sustainable urban farming. Environmental values were strongly indicated, especially biodiversity, ecological regeneration, conservation and stormwater management. There was also an expectation that, in both cases, the revitalisation efforts would uplift the property value. Both projects provided educational and social values to the wider community.

The analysis suggests that small- to medium-scale local biophilic regeneration projects can be initiated and led by community members and require only minor input from professional consultants. The framework provides strong reasons for mainstreaming biophilic revitalisation of stormwater infrastructure at both small- and large-scale.

4.4.6 Conclusions

Regenerating stormwater infiltration basins has drivers, dynamics, and values that can enable sustainable outcomes. The comparative analysis of two case studies revealed that barriers to the wider implementation of a biophilic approach to the revitalisation and repurposing of sumps are mainly socio-institutional, but that these can be overcome at small- and large-scale. The key difference between the small- and large-scale projects was in their governance approach to deliver and maintain the areas. In both cases, leadership was needed to drive the necessary changes.

The results also suggest that it is necessary to develop inspirational, show-case examples and initiate the kind of mainstreaming necessary for biophilic urban regeneration. Quality urban green assets should not be viewed as “optional extras” but as critical elements of successful, value-driven economic developments.

4.5 Publication 5: “Indigenous landscaping and Biophilic Urbanism: case studies in Noongar Six Seasons”

Status: Submitted to *Sustainable Earth* (Appendix G).

This publication addresses sub-question five: *How can social and indigenous contexts be used to deliver BU?*

4.6.1 Introduction

Recently, The Global Biodiversity Outlook 5 revealed that all countries worldwide failed to meet even a single biodiversity target set for 2020 (The Convention on Biological Diversity, 2020). Australia is one of the most biodiverse places on earth (Chapman, 2009), but it has had limited success in preventing its loss. Conservation and rehabilitation help to prevent further decline in species, however, there have been calls for new approaches to facilitate green infrastructure projects with emphasis on biodiversity enhancement strategies (Connop & Nash, 2018; Hes & Du Plessis, 2015).

One of the new accepted approaches is BU. This approach is based on the knowledge that humans have innate connection with the natural world and that this connection needs to be maintain on a daily basis to ensure individual health and well-being (Kellert, 2016a, 2016b). Using an array of nature-based solutions, BU also fosters urban resilience towards better economies, communities and natural systems (Daniels et al., 2020), and it can help with achieving Sustainable Development Goals (SDGs).

Indigenous people have a long history of deploying nature-based solutions to the ways they manage natural environments, however not every country has recognised indigenous environmental knowledge as necessary in building a sustainable economy and sustainable living environments including biodiversity management (WEF, 2020).

This paper examines an emerging overlap between indigenous landscaping and BU in Australia and with application to many cities across the planet. The authors propose a new approach to biodiversity management based on growing indigenous landscaping initiatives in Western Australia.

This research study adopted a case study approach to qualitative inquiry. Several methods of data collection were used for primary and secondary data. The case studies in Western Australia attempt to present how Noongar people and their deep local landscape knowledge can help to make cities more resilient, inclusive, liveable, and how this can lead to more biodiversity gains.

4.6.2 BU and Indigenous Landscaping

The core hypothesis underpinning BU is the biophilia hypothesis formulated by Wilson and Kellert in 1993. This hypothesis states that humans possess an innate tendency to seek connections with nature and other forms of life and these connections should be maintained on a daily basis (Kellert, 2018; E. O. Wilson & Kellert, 1993). Biophilic structures and elements present in urban realms trigger biophilic responses resulting in positive human health outcomes (Alexandra & Norman, 2020; McDonald et al., 2018). Kellert and Calabrese (Kellert & Calabrese, 2015) identified five principles for the effective practice of BD that are compatible with the natural world. However, there seems to be a missing link between the BD agenda and the practices of indigenous landscaping and urban design.

The most successful public spaces are those where the identities of different cultural groups are emphasized and celebrated so people can use those spaces without concerns for being stigmatised (Low et al., 2005). Therefore, it is necessary for BU to address the needs of multicultural societies and provide public urban spaces that could help building social, economic and ecological capital. BD solutions should be developed with consideration for the local cultures, traditions and ecological context.

4.6.3 Noongar Indigenous Landscaping

Indigenous Australians have been the custodians of the lands, waters, fauna and flora for at least 60000 years (Gammage, 2012; Pascoe, 2018) and maintain their connection with the natural world. Indigenous knowledge is based on spirituality that is based on the relationship with the natural environments (Gammage, 2012). Therefore, it would be particularly important to BU practitioners to seek collaboration with the traditional custodians in order to deliver culturally-appropriate development strategies and achieve adequate biophilic outcomes.

The past cultural activity of the Noongar Nation has begun to be recognised legally through the first treaty that attempts to resolve native title claims in Western Australia (Hobbs & Williams, 2018). As part of the emerging integration of Noongar culture into Western Australian life, there is a growing need for wider education, recognition and implementation of Aboriginal knowledge systems (Nannup, 2006; Tucker et al., 2018), ecology and environmental management in urban environments (Robertson et al., 2017).

Schools, public playgrounds, cultural centres and private enterprises are beginning to incorporate local Aboriginal knowledge of Six Seasons in their designs (Kirk, 2017; Turner et al., 2017). Collaborative design processes are applied and include the representatives of different institutions, local Aboriginal communities, artists and landscape designers. This recent revival of Indigenous landscaping supports the efforts of re-wilding the urban environments and enhance the urban biodiversity and supports the BU agenda of building deeper and more meaningful connections between multicultural societies and the natural world.

Western landscape design practices focus on crafting places for enjoyment and prosperous existence, while the traditional Aboriginal perspective emphasises healing, nurturing and looking after the place in anticipation for the return of the ancestors (D. S. Jones et al., 2018).

4.6.4 Stages in the growth of awareness in Six Season Noongar

The three stages in the growth of awareness in Six Seasons Noongar landscaping and environmental management have been proposed. These are early setting aside, regenerating cleared public land, and landscaping the whole city.

4.6.4.1 Early setting aside

The British colony of Western Australia was established in 1826. Soon after, the first settlers began to establish farms, however, they soon realised that the European perceptions were not appropriate about the nature of the landscapes (Seddon, 1972). Despite the difficulties with the introduction of western agriculture, some settlers began to recognise the unique biodiversity and the different six seasons. The knowledge of local fauna and flora came from indigenous sources (Barry, 2016; Hasluck, 1955; Lines, 1994).

During the early planning of metropolitan Perth, some space was set aside to conserve native bush. Kings Park become an urban park, but the majority of the land included was left in its native state (Seddon & Ravine, 1986) and it became a centre of expertise on native flora.

4.6.4.2 Regenerating cleared public land

By the second half of the 20th century, urban planning began recognizing the importance of natural and native spaces in urban environments. Many local nature enthusiasts and botanists helped to systematize local species, helped to establish native and botanical gardens, and supported conservation efforts (Dempster, 2002; Hopper & Gioia, 2004; Seddon, 1972, 2005). Some urban spaces, such as Wireless Hill, were allowed to regenerate themselves and became thriving native landscapes. The regeneration of the Swan River foreshore started in 1955 following the introduction of a new planning scheme and was followed by a growing culture of recognition for native plants providing better biodiversity outcomes. These places still strongly benefit from the indigenous landscape management methods.

In the late 20th century, many domestic and public gardens emerged across Western Australia and helped to establish the native landscaping principles. However, this was in conflict with the modern global trends and fashions. The multicultural population developed their gardens following contemporary trends. Despite the modern fashions, there was a growing sense that the indigenous plants contributed to the sense of place, however, the indigenous interpreters were not usually engaged to share their expertise and help to shape urban green infrastructure.

4.6.4.3 Landscaping the whole city

In the 21st century, the role of the indigenous culture in interpreting the landscape increased significantly. The effort and interest of local governments and communities in planting native gardens became a feature of urbanism in Perth. Interpretation of the Noongar Six Seasons in landscaping helped to better understand the place (Collard et al., 2004). Some institutions, including schools, established their own Six Seasons Gardens to use the space for educational and cultural purposes (City of South Perth, 2019; Kirk, 2017; Watkins, 2017; Wheatbelt NRM, 2016). Educational programs and guided tours on the Noongar Six Seasons have been offered to the wider community and tourists (Botanic Gardens and Parks Authority, n.d.; Nannup, 2006). There has also been an increased interest in growing urban forests using native tree species and regenerating urban wetlands (Byrne, 2006).

The biodiversity in Metropolitan Perth is abundant (Hoffman et al., 2019) and this movement to increase the use of native plants has been growing, however, it has not been fully integrated into indigenous culture.

4.6.5 Six Seasons case studies

The paper examines selected indigenous landscape case studies from Western Australia to illustrate the concepts presented. Two case studies are Aboriginal Six Seasons Gardens: Ballardong Noongar Six Seasons Garden, Muminbulah Wilak Six Season Garden in Jandakot. The third case study is The Bushland Garden in York.

4.6.5.1 Ballardong Noongar Six Seasons Garden

The garden was established in 2009 on the grounds of the Residency Museum in York, Western Australia. It was a collective effort of the Wheatbelt NRM, the Ballardong Noongar community, a local high school, individual and corporate sponsors and volunteers. The project is a symbolic garden walk and it represents the past, the presence and the future of Ballardong Noongar Budjar and their meanings to the Ballardong Noongar people (Shire of York, n.d.). The native flora and fauna bear traditional meaning an importance in the garden. The plants would serve as the season-changing indicators, food, medicine or water sources. The animals were traditionally valuable food sources in particular seasons and important spiritual and cultural totems (Collard et al., 2004). The garden plays a symbolic role in order to educate the visitors on spiritual, ecological and cultural level.

4.6.5.2 Muminbulah Wilak Six Seasons Garden

The garden was built by the ATCO Company in Jandakot between 2018 and 2019. It is considered a cultural and educational tool telling the story of Noongar Culture and the role of six seasons (WA Parks Foundation, 2021). The design was inspired by a painting from a local Indigenous artist – Deborah Bonar (ATCO, 2018). The garden was designed by an Indigenous consultant in collaboration with the local Elders, and built by Indigenous landscaping companies (J. Scriven, personal communication, June 20, 2018). The garden is divided into six sections symbolising each season. The plant palette correlated with the plants available for food, medicine, shelter and other resources during each season. The meanings of the sculptures, the footpath and the water feature are derived from the Indigenous stories.

4.6.5.3 The Bushland Garden

The garden was initiated by two York residents and built by local volunteers between 1993 and 2002. In 2005, The York Branch of the Wildflower Society assumed responsibility for its maintenance and development. One of the main objectives for the establishment of the garden was to promote and encourage the growing local native plant species from York Shire. The garden is a demonstration of six seasons' flowering plants and presents, in fact, many features of a Six Seasons garden. However, it is not making the most of this cultural connection (Watkins, 2017). Many groups and local authorities have contributed to the maintenance of the garden and continue promoting it as an important educational green urban space in York (E. Ayling, personal communication, April 22, 2021).

4.6.6 Why enable Indigenous landscaping?

Some of the qualities of the indigenous and native gardens have been derived from the case studies. These have been divided into three categories: Purpose, Design, Flora fauna and abiotic elements. The qualities suggest that there are some common purposes for the establishment of both indigenous and native gardens. These are providing spaces for education, memorials and gatherings. Indigenous gardens provide space for cultural expression, profound connection with land, flora and fauna. In the case of the native garden, the main focus was on natural environment conservation efforts and use of native plants in private gardens.

There are many good reasons for including Indigenous and native approaches in urban landscaping. However, there would be several reasons for BU to try and incorporate an inclusive approach to indigenous landscaping: cultural, educational and professional values amongst others.

4.6.7 How does Indigenous landscaping help BU?

BU delivers multiple benefits provided by urban nature: economic benefits of green infrastructure, human health and welfare benefits, and deeper motivation for nature conservation and biodiversity regeneration (Beatley & Newman, 2013; Marinelli, 2021; Sanderson et al., 2018). Based on the insights from the case studies, we discuss why the more inclusive approach to indigenous cultures can assist BU with the delivery of crucial benefits. The key reasons are:

- The importance of place

- The importance of inclusive culture
- The importance of biodiversity

4.6.8 Conclusions

The paper suggests that BU and Six Seasons landscaping can inform each other and could help mainstreaming indigenous and native landscaping strategies. Indigenous knowledge and approach could be more systematically incorporated into the design of green urban infrastructure and delivered at the urban scale, may provide appropriate space where traditional knowledge and values could be learned, cultivated and celebrated.

There are many opportunities for the application for the Noongar Six Seasons interpretive landscaping in Perth as part of mainstreaming BU. The future of BU in Perth and other cities depends on whether the design professionals have collaborated with historians and local communities to create a deeper sense of place for all residents using the same land as those from deep history.

5. Results and Discussion

The results and discussion follow the three implementation strategies. They are divided into three sections and three subsections representing overarching solutions for more feasible and effective delivery of BU. These relate to the overarching implementation strategies presented in Figure 1.2 in Chapter 1.

Section 5.1 Funding: Land Value Capture
Section 5.2 Planning and Design:
Subsection 5.2.1 Bioregional Planning
Subsection 5.2.2 Street Planning and Design
Subsection 5.2.3 Stormwater Infrastructure Design
Section 5.3 Context: Social and Indigenous

Based on the replicable case studies, the solutions presented include the tools, strategies, design elements, attributes, approaches, values, incentives and drivers needed to facilitate the delivery of biophilic urban regeneration projects.

5.1 Funding: Land Value Capture

This section discusses the results from Publication 1. The main focus of the study in this publication was to establish how strongly biophilic elements impact land and property values. The authors examined whether land value capture could be used to fund the mainstreaming of BU projects. They suggest a possible funding mechanism to enable BU to be mainstreamed as a part of urban regeneration.

This study shows how the regeneration of blue and green infrastructure can become an incentive for economic development. The analysis of the selected case studies has shown that increases in land values could be generated through a strategic design of the public amenities using the principles of BU. It has been estimated that the proximity of traditional urban green and blue infrastructure to real estate can increase property values up to 50% of the original value. Certain biophilic structures, such as rooftop gardens, generate an uplift in property value between 2 and 11% depending on accessibility and the type of use. The results for green walls show an increase in property value between 3.9 and 15%. The authors concluded that the value increase for properties with biophilic structures needs further research to more accurately estimate the economic gains for investors.

The literature review and available data on executed biophilic projects indicate that alternative ways of financing new public investments in urban developments are needed. The analysis of the High Line regeneration project in New York revealed how incremental tax revenues created by higher real estate values around the park would outweigh the costs. Based on that, the authors proposed implementing a mechanism of land value capture as one way of funding biophilic projects by private investors. The land value capture mechanism could be used to calculate approximate land value increases and allocate the profits towards funding a biophilic urban infrastructure. Extra taxation revenues from biophilic regeneration projects can be forecast and included in future budgets as a means of paying for biophilic urban infrastructure costs upfront. An increase in land value may also attract private investors to open businesses within the development.

The analysis of the case studies revealed some strategies for the successful delivery of biophilic urban projects. For example, a public-private partnership can facilitate the execution of a biophilic regeneration project. Additionally, marketing, high-profile supporters, and political and federal support enable biophilic regeneration projects. Furthermore, well-executed and marketed projects lead to further replications and show-case examples, which can drive mainstreaming of BU. These findings demonstrate how biophilics could be better implemented by governments and private investors as a core factor in urban regeneration projects. BD projects could be mainstreamed into urban policies on the grounds that they add value to land and properties.

5.2 Planning and Design

5.2.1 Bioregional Planning

This section discusses the results from Publication 2. The main focus of this study was on how the natural features that are being introduced in an urban environment can improve bioregional outcomes. The authors also tried to identify how bioregionalism and BU are related so that cities could integrate BD strategies into their bioregional strategies. They suggest several ways that BU can help with the bioregionalism agenda. The three elements examined to illustrate the links are ecosystem services, biodiversity and sense of place. The results are summarised in Figure 5.1 below:

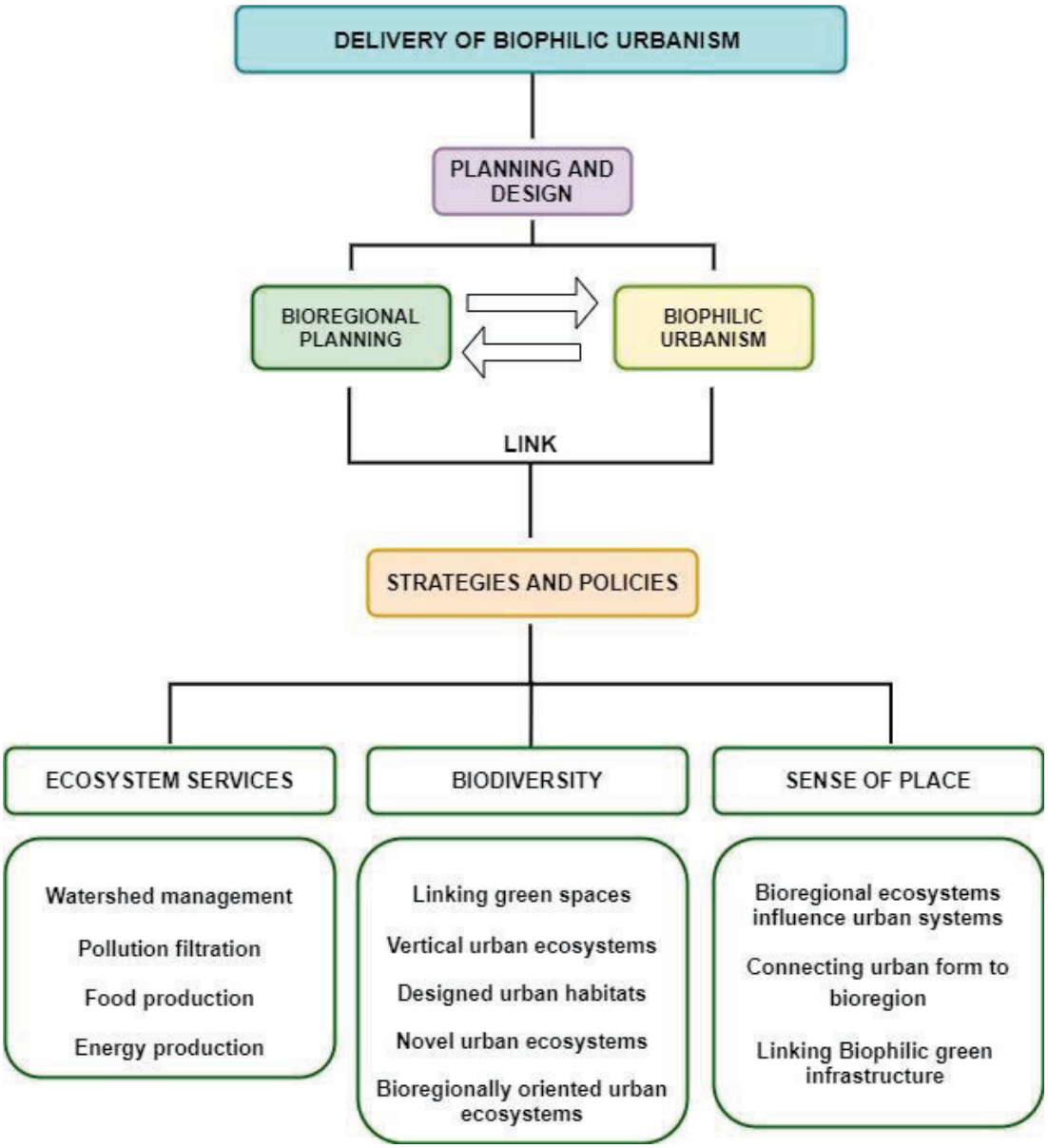


Figure 5.1 Links between bioregional planning and BU. Source: Author.

Ecosystem Services

The analysis of the selected case studies reveals possible design strategies and biophilic elements that can support a bioregional agenda. Biophilic structures, such as green roofs, green walls and rain gardens can assist bioregional watershed management. They can slow and retain stormwater runoff and filtrate pollution. Moreover, vegetated rooftops can assist with green energy production. Photovoltaic panels have been shown to be more efficient when installed on vegetated rooftops. Provisional ecosystem services, such as food, can be produced on green rooftops, green walls and in verge gardens.

Biodiversity

The study shows that new bioregionally-oriented urban ecosystems can be created using biophilic urban strategies. It has been suggested that the ecosystems created in urban areas may be more biodiverse than natural ecosystems in the countryside as urban density helps to link green spaces, and as the case of Singapore demonstrated. High-rise buildings provide space for novel vertical ecosystems which can help with regenerating bioregional ecosystems.

Sense of Place

A bioregional approach to urban design helps to create a sense of place. One of the strategies to achieve that is to connect the urban form to the wider bioregion. It is possible to design biophilic structures that form corridors connecting the city to its bioregion. Those structures should display the characteristics of the bioregional ecosystems and be inter-connected so they form biophilic urban systems.

Biophilic urban infrastructure, such as green walls, green rooftops and other elevated greenery, can create channels between urban habitats and the habitats of a particular bioregion. The case study of Vitoria-Gasteiz shows how day-lighting an urban stream, planting a naturalised embankment with native riparian species and covering the envelope of an adjacent building with native plants connects the inner-city ecosystem with the bioregional ecosystem.

5.2.2 Street Planning and Design

This section discusses the results from Publication 3. The authors developed a theoretically and practice-informed biophilic street design framework. The framework was applied to four examples of a street revitalisation project to illustrate its utility. The results have been summarised in Table 5.1 below:

Table 5.1 Application of the framework for biophilic streets design in four analysed street projects. Credit: Agata Cabanek, Maria Elena Zingoni de Baro and Peter Newman.

FUNCTIONS OF A BIOPHILIC STREET	BIOPHILIC DESIGN ELEMENTS APPLIED TO ANALYSED STREET PROJECTS			
	Gasteiz Hiribidea, Vitoria-Gasteiz, Spain	**Downtown Berkeley, California, USA**	**SW Montgomery Street, Portland, USA**	**Green Lanes, Melbourne, Victoria, Australia**
Traffic Planning	- prioritising pedestrians and cyclists; - enhancing facilities for transit; - slowing traffic.	- prioritising pedestrians and cyclists; - enhancing walkability standards; - reducing existing traffic lanes; - lowered traffic speed.	- prioritising pedestrians and cyclist (kerb-less paving); - narrowing existing traffic lanes; - lowered traffic speed; - sections of the street closed to traffic.	- limited traffic (local only) - shared space between pedestrians and vehicles.
Energy Management	- energy reduction due to ecological runoff treatment; - insulation capabilities of green walls and roofs systems; - heat island effect mitigation by tree canopies, landscaping and waterbodies.	- energy reduction due to ecological runoff treatment; - insulation capabilities of green walls and roofs systems; - heat island effect mitigation by tree canopies, landscaping and waterbodies.	- energy reduction due to ecological runoff treatment; - insulation capabilities of green walls and roofs systems; - air temperature regulation through landscaping.	- energy reduction through “green insulation”; - heat island effect mitigation through landscaping and miniature raingardens.
Stormwater Management	- retention in underground cisterns; - Infiltration via permeable surfaces	- retention in underground cisterns; - Infiltration via permeable surfaces;	- Infiltration via permeable surfaces;	- Infiltration via permeable surfaces; - retention and bio-filtration

	- purification using bio-filters (plants); - recycling via green wall and roof systems; - bio-filtration through	- retention and bio-filtration through swales, raingardens; - purification using bio-filters (plants); - recycling via green wall and roof systems; - bio-filtration through daylighted stream.	- retention and biofiltration through stormwater planters and raingardens; - purification using biofilters (plants); - recycling via green wall and roof systems.	through raingardens; - recycling via green wall systems.
Biodiversity Management	- green walls, roof and living stream designed for biodiversity enhancement and ecological restoration; - daylighted and restored stream with riparian plants provide habitats for wildlife and facilitate species migration.	- green walls designed for biodiversity enhancement and ecological restoration; - daylighted and restored stream with riparian plants provide habitats for wildlife and facilitate species migration.	- green walls designed for biodiversity enhancement and ecological restoration; - use of native species - green corridors connect fragmented green areas; - raingardens provide habitat for wildlife.	green walls, planters, miniature raingardens designed for biodiversity enhancement and ecological restoration; - habitats for wildlife and facilitate species migration.
Street Furniture	- integrated street furniture; tree pits and sittings expressing ecological sensitivity;	- parklets in parking spaces; - natural buffer between sidewalks and traffic; - public art supporting environmental awareness; - permeable paving facilitating rainwater infiltration.	- green wall and roof systems; - permeable paving facilitating rainwater infiltration.	- planter-boxes with irrigation systems; - green wall system hanging baskets and miniature raingardens; - permeable paving facilitating rainwater infiltration.
Activity and Education	- activity features for kids:	- interactive play equipment;	- interpretive plates and signs;	- green infrastructure serves

	sculptures, water features; - informative design of green walls and roofs; - interpretive plates and signs; - exposed ecological systems.	- interpretive plates and signs; - exposed ecological systems; - parklets and temporary installations.	- exposed ecological systems; - green infrastructure serves educational and research purposes; - activation of shopfronts supporting community living.	educational and research purposes.

Application of the framework to the selected examples of street revitalisation projects show that basic urban street functions can be delivered or enhanced using the strategies of BD. The results demonstrate how urban streets can be designed so they provide space for the development of nature-based water management systems serving ecological as well as educational purposes. Structures like green walls and roofs can support urban biodiversity and significantly reduce surface temperature on building envelopes, and so save on heating and cooling energy costs.

By reducing existing traffic lanes and limiting the traffic, biophilic streets can bring more residents outdoors. Prioritising pedestrians and cyclists would facilitate biophilic experiences. It has been shown that purposively designed street furniture can support urban natural systems. Elements such as planter boxes or mobile green walls can be distributed in a way that facilitates connectors between urban nature and bioregional nature.

The two factors limiting the implementation of biophilic street design are the initial costs of implementation and spatial constraints. These can be overcome by introducing cost-effective, temporary and mobile biophilic installations instead of costly permanent structures. The results from the case study analyses are synthesised in Figure 5.2 below, which shows the potential multiple urban benefits that could be realised if street designers, planners and landscape architects incorporated the strategies of BU into the design process.

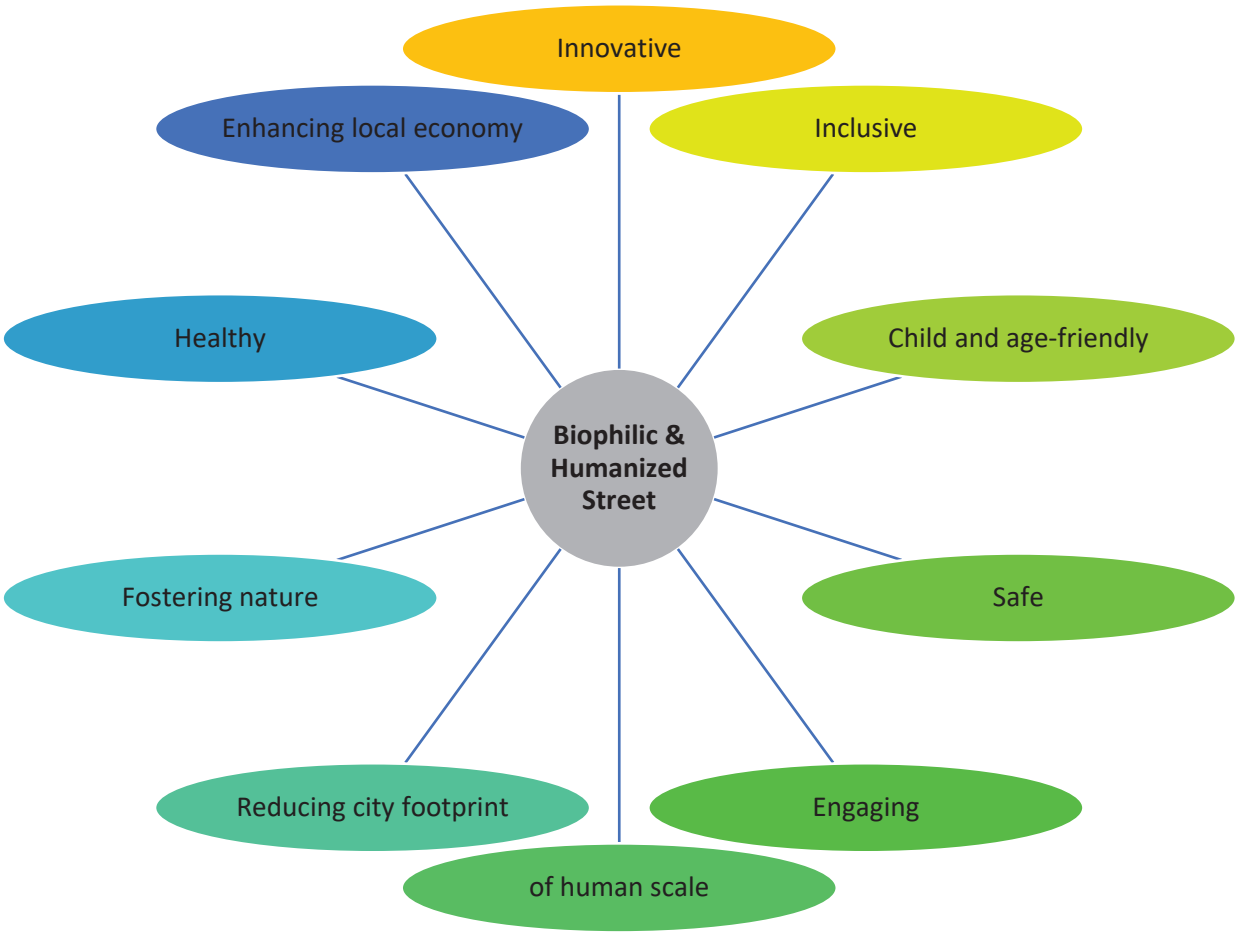


Figure 5.2 The multiple urban benefits of a biophilic streets. Credit: Author.

5.2.3 Stormwater Infrastructure Design

This section discusses the results from Publication 4. The authors explored new ways of integrating regenerative and BD into urban design and planning in a local context; in this case, Perth, Western Australia. An analytical framework was developed and applied to the case studies to identify the actors, drivers, strategies, constraints, and values underpinning the successful delivery of the biophilic projects. The results are shown in Table 5.2 below:

Table 5.2 Comparative analysis of the WGV Sump Park and the Green Swing Sump Garden. Credit: Agata Cabanek, Maria Elena Zingoni de Baro, Peter Newman and Joshua Byrne.

	The Green Swing Sump Garden	The WGV Sump Park
Actors	Group of owner-builders and individuals with common interests and values Professional consultant	Community Professional consultants (engineering and environmental and landscape design) Local Government: City of Fremantle State Government Agencies: DevelopmentWA
Drivers	Social (Building a sustainable community; Creating space for community collaboration and enjoyment; Providing inspiration for the wider community; Beautification of the area surrounding the development) Economic (Self-funded; Uplift property value) Environmental (Increase urban green space; Contribute to local biodiversity)	Social (Innovation through Demonstration model; Enhance attractiveness of the area surrounding the development) Economic (alignment of key stakeholders' interests; Budget availability; Uplift property value) Environmental (Increase of urban green space; Biodiversity enhancement; Addressing canopy loss)
Strategies	Private initiative Developing an innovative approach to increase urban green space through the creative use of the underutilised space of the adjacent sump	Public-private partnership Innovation by Demonstration model One Planet Living framework Water-sensitive urban design
Constraints	Model development Concerns at community level Concerns at local government level, mainly health and safety issues Obtaining permissions and approvals	Concerns at government level - flood modelling issues, health and safety issues Obtaining permissions and approvals

	Lack of clear policy guidelines	
Values	Anthropocentric (Sustainable urban living; Community building; Place-making; Sustainable urban food production) Ecocentric (Local biodiversity enhancement)	Anthropocentric (Sustainable urban living; Community building; Place-making; Monetary value enhancement) Ecocentric (Environmental regeneration and conservation; Water management)

Analysis of the selected case studies revealed that the strategies used to deliver the biophilic regeneration projects were responds to the objectives and the scale of each project. The strategies involved volunteers for the small-scale project (The Green Swing sump garden) and professional advice for the larger-scale project (The WGV sump park). The drivers highlighted by the stakeholders of the sump garden focused mainly on the social and environmental benefits, while the stakeholders of the sump park aimed to demonstrate how to effectively utilised space in a medium-density development by embracing the innovation through demonstration model. In regard to the constraints affecting the delivery of biophilic regeneration initiatives, the similarities between the projects were clear. The concerns at the local community and at the government level were the lengthy process of obtaining relevant approvals and health and safety regulations. The values expressed by the stakeholders in the two cases showed some similarities too, such as community building, innovations in sustainable urban living, placemaking and food production. Environmental and ecological values such as environmental regeneration, biodiversity enhancement, and sustainable water management were cited in both cases. The stakeholders aimed at demonstrating innovative approaches to increase urban greenery.

This research project revealed that the main challenges for the delivery of stormwater biophilic regeneration projects are legal status, path dependency and leadership. The analysis shows that new government approaches are crucial to allow innovative biophilic initiatives in the urban realm. Additionally, dissemination and availability of information on successful biophilic urban projects to a wider audience, would encourage replication and facilitate mainstreaming.

5.3 Context – Social and Indigenous

This section discusses the results from Publication 5. The main focus of this study was on how Indigenous landscaping knowledge, values and management methods can assist with BU. The analysis of the case studies allowed to extract qualities in focus for Indigenous and Local Native gardens and these are Purpose, Design, Flora and Fauna, and Abiotic Elements. The results show certain similarities and differences between indigenous and native landscaping. Despite the differences, the authors suggest that both approaches bring many benefits to the urban built and natural environments. However, there are several reasons why BU should try and include more of this approach towards Indigenous landscaping.

In the table below (Table 5.3), the authors suggest the main reasons for Indigenous landscaping to assist with mainstreaming and delivery of inclusive BU.

Table 5.3 Indigenous landscaping supporting BU: areas of focus. Credit: Agata Cabanek and Peter Newman

Why enable Indigenous landscaping?	How enable Indigenous landscaping?
Cultural value • Cultural immersion into landscapes is the foundation of a sense of place; • Native plant projects should be able to provide more meaningful interpretation of the plants as in their use over deep history;	**The importance of place** • The sense of place is the basis of thriving cities, building social and economic capital; • The sense of place in a city is bound up in a combination of a physical/natural environment and the social/cultural environment; • The most successful places achieve a balance between those environments and provide space for multicultural societies to thrive;
Educational value • Indigenous knowledge enables biodiversity to thrive;	**The importance of inclusive culture**

• Integration of Indigenous cultural uses of plants in every stage of a planned project; • Planting natives provide educational outcomes and promotes traditional uses of plants; • Indigenous landscaping can assist with fire and water management;	•Emphasizing cultural meanings of designed landscapes are necessary for a successful sense of place; •Native plants used in designed landscapes provide cultural and spiritual meanings and help migrants to develop a new sense of place; •Indigenous meanings are the deepest meanings for a place;
Professional value • Indigenous landscaping can help with creating a more biodiversity-centred cities; • Indigenous landscaping knowledge could be transferred into landscape design and practice as a new kind of BU related to a particular city and its cultures;	**The importance of biodiversity** • Indigenous landscaping can conserve and regenerate biodiversity; • Bringing Indigenous landscaping to cities in community-based biophilic projects would help biodiversity management

The findings suggest that BU and Six Seasons landscaping can inform each other and help mainstreaming Indigenous and native landscaping strategies. This Indigenous dimension to management of the natural environment could lead to the enabling of local policies advocating green urban infrastructure and biodiversity management.

6. Conclusions and Recommendations

This thesis has applied the concept of BU and design to evaluate potential strategies and tools for its efficient and financially viable delivery. By developing strategies and tools to facilitate the implementation of BU, this thesis argues that it is possible to deliver healthier and more liveable urban environments as well as habitats supporting urban biodiversity. This approach, therefore, is better able to integrate human and ecological dimensions than previous approaches which have not prioritised human health and well-being.

This research has combined the concepts of biophilia (E. O. Wilson, 1984), BU (Beatley, 2011a), BD (Kellert et al., 2008) and bioregional planning (Newman & Jennings, 2008). The concepts of BU and BD have previously been applied in the design and development of many cities; however, a gap in our understanding of how those concepts can be implemented remains. Since BU first emerged as an important policy area for delivering tangible benefits to cities, new strategies have been needed to facilitate its successful implementation. The focus of this thesis was to undertake a closer analysis of what can be achieved by stakeholders if BU was to guide urban developments at different scales.

Three aspects of urban development were selected to guide the research: funding scheme, planning and design and context. The selection criteria for projects to include in the analysis emerged from the results of the literature review, which revealed the knowledge gaps concerning the implementation of BU. Further, the five research sub-questions were assigned to three development aspects and formed the foundation for the five publications and the selection of the analysed case studies.

Publication 1 sets out how the concept of land value capture, now commonly used in delivering transport projects, can be applied to BU projects and support their funding. In Publication 2, the authors show how traditional bioregional planning can be adapted to bring a more BU outcome by applying its principles in a more urban context. Publication 3 uses the principles of new urbanism-based street planning to enable BU to be built into this approach to street revitalisation. In Publication 4, the authors analysed a stormwater project to show how some core implementation principles of local planning and design—community-engagement, specialised design expertise, creativity and local government commitment— can be applied to BU. The final paper (Publication 5) uses the cultural context of regional indigenous

landscape approaches to show how BU can use these concepts in an urban context.

Selected case studies from cities around the globe have been analysed. Publication 1 examined examples from Seoul (South Korea), Birmingham (United Kingdom) and New York (United States). Publication 2 examined case studies from Singapore and Vitoria-Gasteiz (Spain). Publication 3 analysed examples from Portland and Berkeley (United States), Melbourne (Australia) and Vitoria-Gasteiz (Spain). Publication 4 analysed case studies from White Gum Valley and Lathlain in metropolitan Western Australia. Publication 5 presented examples from Jandakot, Perth and York in regional Western Australia. The examples of biophilic projects analysed were selected based on accessibility, open-sourced data availability and representation of biophilic elements, solutions and experiences.

A multi-case study approach of qualitative inquiry was used to analyse potential methods of financing biophilic urban developments and to explore the tools, attributes, design elements, approaches, values, incentives and drivers facilitating the delivery of biophilic urban regeneration projects (Publications 1 to 4). Further, a social and indigenous context of BU was examined to better understand how history, local and indigenous landscape knowledge can facilitate the delivery of culturally-appropriate biophilic urban projects (Publication 5).

In response to the overarching research question—*What tools and strategies can help implement BU in a way that integrates human end ecological dimensions?*— the evidence analysed in the preceding chapters and the publications suggest numerous tools, approaches and strategies for the successful delivery and mainstreaming of biophilic urban projects and initiatives. These are summarised below:

1. New financing schemes: Biophilic urban projects have been built in many locations around the world. However, the success stories behind them are rarely disseminated to a wider audience. Developers and local authorities rarely report on the processes of achieving biophilic urban projects (Publication 1 and 3). A better understanding of how biophilic projects can be funded, planned and designed is essential to enable effective delivery of BU at a city scale. To encourage and facilitate designs based on BU strategies in urban regeneration projects, local governments should consider alternative ways of financing these new investments. A mechanism of land value capture has been proposed as one way of funding biophilic projects by private investors. This mechanism could

be used to calculate approximate land value increases and allocate the profits towards funding biophilic urban infrastructure. This increase in land value can be used to attract private investors to deliver new businesses in the area (Publication 1).

2. Climate change and biodiversity loss: In recent years, there have been calls for action to tackle the consequences of climate change, to address biodiversity loss and disturbance of ecosystem services (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019; Masson-Delmotte et al., 2018). Strategically implemented BU, could assist with these challenges and should become part of climate change strategies and biodiversity loss for governments, development agencies and private businesses (Publication 5).

3. Healthy ecosystems: BD and BU are anthropocentric design concepts. In this era of environmental and climate emergency, BD and urbanism must not only focus on the health and wellbeing of humans, but on the health and wellbeing of whole urban ecosystems and beyond (Publication 5). The state of urban biodiversity and the health of its fauna and flora must be taken into consideration at the initial design stage of a biophilic project. Buildings and their indoor environments, roofs, balconies and façades should all be designed in a way so that they connect with the natural world outside the buildings. Landscaped areas should be designed within the same biophilic paradigm, so the inside-out and outside-in are interconnected and complementary (Publications 2 and 3).

4. Innovative approaches and economic benefits: Biophilic urban projects, including regeneration projects, can provide economic benefits such as increases in property value, cost savings on cooling and heating and extended life-spans of landscaping materials (Publications 1, 3 and 4). The measurable change resulting from the implementation of BU must be captured to prove financial gains. Local authorities should demonstrate increased policy ambitions and development stakeholders should be able to demonstrate the need to implement innovative sustainable solutions (Publications 2, 3 and 4). A monetary value estimate is necessary to encourage wider uptake of BD strategies.

5. Space availability in urban context: Regenerating the most common urban open spaces—the streets—by implementing biophilic urban design principles leads to multiple urban benefits, as shown in Publication 3. The four analysed street examples demonstrate how biophilic streets can be built in different locations, climates, city typologies and urban structures. Multiple design solutions, when used in conjunction with and fulfilling the objectives of BU, can deliver spaces that resulted in economic, environmental and social benefits (Publication 3 and 5). Integrating environmental approaches into the functional design of streets can contribute to a community's economic and social enhancement. Biophilic streets could form a network connecting urban nature with the bioregion, thereby directly supporting its biodiversity. The proposed biophilic streets design framework could help to improve urban infrastructure so that it delivers restorative and health-promoting outcomes across any city. The framework could be used by policymakers and designers to move from theoretical and imaginative BU discourse to real-life projects and urban interventions.

6. Scale and the governance: Analysis of the stormwater regeneration projects revealed that the governance approach to delivery and maintenance of biophilic projects depends on the size and scale of a particular project. Small-scale initiatives, such as a community garden (Publication 4), can be initiated and successfully led to completion by a group of community members with casual support from professionals. A large-scale project, such as a neighbourhood park (Publication 4), requires a partnership between various stakeholders (professionals, community, developers and local governing bodies) and a fully-professional assessment process. The engagement of like-minded stakeholders guarantees the success of a biophilic project.

7. Biophilic regeneration of urban infrastructure: Regenerating modern urban infrastructure by applying biophilic strategies to achieve biophilic experiences: Results from the analysis of the biophilic regeneration of stormwater basins in Perth demonstrated that many more benefits from urban infrastructure can be achieved if the principles of BU and BD are deployed at different scales during the planning and design process (Publications 3 and 4).

8. Urban density and new nature: Urban density does not prevent nature from thriving, but it can become the opposite. By applying the principles of BU in densely built-up neighbourhoods, Singapore was able to bring nature more

intensely into the daily life of urbanities (Publication 2). Density may assist with building vertical ecologies, where a kind of new nature, through new habitats, develops that fulfils the functions of the original ecosystems replaced by the city and which contributes to bioregional outcomes.

9. Ecology and aesthetics: An assessment of human needs is often reduced to aesthetic and results in underperforming urban nature (Publication 5). The monoculture of lawns and popular ornamental plant species (often non-native) provide primarily aesthetic experiences. The common scenario in many urban landscape projects is that the designers fulfil the client's desires for an attractive landscape design while ignoring pre-existing urban ecological networks. This needs to change and appropriate policies need to be introduced to shift people's priorities.

6.1 Further Research

The findings from this research revealed that there are many knowledge gaps, structural barriers, and governance issues that need to be overcome in order to efficiently deliver and mainstream BU. The following recommendations for future research may help to facilitate the delivery of BU:

- When opportunities for new urban development or regenerative projects arise, a conscious design strategy presenting BU objectives can deliver outcomes that are more liveable and regenerative. Further research is needed into the delivery strategies of biophilic urban projects where BD strategies were considered at the initial stage of the projects and continued to be implemented throughout the remaining phases.

- A clear vision of how to implement BU at a local level is needed. Strong leadership and broad community support are necessary for local biophilic projects to take place and to ensure objectives are met. Effective implementation of BU must be supported by policymakers to link climate, biodiversity and health policies. Further research into the systematic implementation of BU and how to deploy the BD solutions at different scales, could help to establish local guidelines and best practice principles in relation to the local environmental, social, historical and cultural context.

- Modern urban and landscape design must not continue to be out of balance with nature. Ecosystem disruptions lead to outbreaks of viral and microbial disease. BU has the tools to build ecosystem services that can stop infectious disease transmission. Further research is needed to collect data on how certain biophilic features and designs help to reduce the spread of infectious diseases.

- In green spaces in urban environments that contain wildness, biodiversity thrives, and nature manages itself with minimal human intervention. How such pockets of wildness in urban environments affect the urban residents remains to be answered. Research into the impact of pockets of wilderness on human health and well-being would help in the planning and design of biodiverse biophilic urban places.

- Further research is needed to monitor and quantitatively and qualitatively evaluate the performance of biophilic streets and their countering impact on climate change, environmental degradation and biodiversity loss. Evaluations should also address cost-effectiveness.

- Biophilic cities are smart cities. Technologies used in smart cities can be used to measure the biophilic effects of urban nature. Satellite images provide information on the use of biophilic places, the data obtained would aid the investigation of the effect of biophilic elements on human health and wellbeing as well as the health of particular ecosystems and their qualities. Visitors into the biophilic spaces, for instance, could report via mobile phones their preference for distinct biophilic structures or solutions. Further research should look at how new technologies can help to connect urban inhabitants to local and bioregional nature.

- Further research is needed on how BU should incorporate human history, social and indigenous contexts and individual stories into the design of buildings and open spaces.

- To ensure adequate psychological and ecological benefits, the needs of different ethnic, cultural, indigenous, or immigrant groups need to be recognised and addressed by designers. It is necessary to consider these

factors in urban design practices in order to deliver spaces that improve and maintain good health and wellbeing and strong, harmonious communities.

- Urban planners need to consider how the size and type of urban green spaces may influence improvements in health and wellbeing. For instance, which types of urban green spaces are most conducive to facilitating physical activity?

- It is important to mention that most research has a limited impact on public policies or strategies. Most scientific papers are inaccessible to policymakers, urban planners and designers. It is often the case that new tools, frameworks, and strategies never influence public policies or design and management practices. Showcasing successful examples of sustainable and biophilic urban solutions and communicating their benefits in clear and appropriate formats, using a diversity of media, is essential to increase if we are to increase awareness and understanding of the enormous potential benefits that BU offers among policymakers and other stakeholders. The result must be disseminated to the wider public free of charge to encourage similar initiatives. The analysis and results of the selected case studies must clearly show step-by-step how to achieve sustainable goals. Showing how the results translate into financial gains is another important step toward mainstreaming biophilic urbanism.

Exegesis References

Alexandra, J., & Norman, B. (2020). The city as forest - integrating living infrastructure, climate conditioning and urban forestry in Canberra, Australia. *Sustainable Earth*, *3*(1), 10. https://doi.org/10.1186/s42055-020-00032-3

Ascher, K., & Uffer, S. (2015). The High Line Effect. *CTBUH New York Conference*.

ATCO. (2018). *ATCO's vision for reconciliation is building a better Australia, by building better relationships, understanding and trust in partnership with Aboriginal and Torres Strait Islander peoples*.

Australian Government. (2010a). *Australia to 2050: future challenges*.

Australian Government. (2010b). *Our Cities. The challenge of change.*

Bain, Lesley., Gray, Barbara., & Rodgers, Dave. (2012). *Living Streets : Strategies for Crafting Public Space.* John Wiley & Sons.

Barry, B. (2016). *Georgiana Molloy: The Mind That Shines*. Picator Australia.

Beatley, T. (2009). *Biophilic Urbanism: Inviting Nature Back to Our Communities and Biophilic Urbanism: Inviting Nature Back to Our Communities and Into Our Lives Into Our Lives*.

Beatley, T. (2011a). *Biophilic Cities: Integrating Nature into Urban Design and Planning*. Island Press.

Beatley, T. (2011b). Biophilic Cities: What Are They ? In *Biophilic Cities: Integrating Nature into Urban Design and Planning*. https://doi.org/10.5822/978-1-59726-986-5

Beatley, T. (2012). Green cities of Europe: Global lessons on green urbanism. *Green Cities of Europe: Global Lessons on Green Urbanism*, 1–234. https://doi.org/10.5822/978-1-61091-175-7

Beatley, T. (2016a). Biophilic Architecture and Design. In *Handbook of Biophilic City Planning and Design*. https://doi.org/10.5822/978-1-61091-621-9_15

Beatley, T. (2016b). *Handbook of biophilic city planning and design*. Island Press. https://doi.org/10.5822/978-1-61091-621-9

Beatley, T. (2016c). The Power of Urban Nature: The Essential Benefits of Biophilic Urbanism. In *Handbook of Biophilic City Planning and Design*. https://doi.org/10.5822/978-1-61091-621-9_1

Beatley, T. (2017). Biophilic Cities and Healthy Societies. *Urban Planning*, *2*(4). https://doi.org/10.17645/up.v2i4.1054

Beatley, T., & Newman, P. (2009). *Green urbanism down under : learning from sustainable communities in Australia*. Island Press.

Beatley, T., & Newman, P. (2013). Biophilic Cities Are Sustainable, Resilient Cities. *Sustainability*, *5*(8), 3328–3345. https://doi.org/10.3390/su5083328

Biophilic Cities Network. (n.d.). *Biophilic Cities*. Retrieved November 26, 2020, from https://www.biophiliccities.org/

Bioregional. (2015). *WGV by LandCorp – One Planet Action Plan*.

Birkeland, J. (2012). Design Blindness in Sustainable Development: From Closed to Open Systems Design Thinking. *Journal of Urban Design*, *17*(2), 163–187. https://doi.org/10.1080/13574809.2012.666209

Birkeland, J. (2018). Challenging policy barriers in sustainable urban design. *Bulletin of Geography*, *40*(40), 41–56. https://doi.org/10.2478/bog-2018-0013

Blau, M. L., Luz, F., & Panagopoulos, T. (2018). Urban river recovery inspired by nature-based solutions and biophilic design in Albufeira, Portugal. *Land*, *7*(4). https://doi.org/10.3390/land7040141

Botanic Gardens and Parks Authority. (n.d.). *Gnarning Walk*. Retrieved August 31, 2020, from https://www.bgpa.wa.gov.au/kings-park/events/walks-and-tours/self-guided-walks/boodja-gnarning-walk

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010a). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, *97*(3), 147–155. https://doi.org/10.1016/j.landurbplan.2010.05.006

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010b). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, *10*(1), 456. https://doi.org/10.1186/1471-2458-10-456

Browning, W., Ryan, C., & Clancy, J. (2014). 14 Patterns of Biophilic Design. *Terrapin Bright Green,LLC*.

Bruyère, C., Holland, G., Prein, A., Done, J., Buckley, B., Chan, P., Leplastrier, M., & Dyer, A. (2020). *Severe Weather in a Changing Climate* (Issue 2).

Buijs, A. E., Elands, B. H. M., & Langers, F. (2009). No wilderness for immigrants: Cultural differences in images of nature and landscape preferences. *Landscape and Urban Planning*, *91*, 113–123. https://doi.org/10.1016/j.landurbplan.2008.12.003

Byrne, J. (2006). *The green gardener : sustainable gardening in your own backyard*. Viking.

Byrne, J. (2017). *A Thriving Community - Gardening Australia*. Australia Broadcasting Corporation.

Byrne, J. (2018). *A Different Approach - Gardening Australia*. Australian Broadcasting Corporation.

Byrne, J., Green, M., & Dallas, S. (2018). WSUD Implementation in a Precinct Residential Development: Perth Case Study. In A. K. Sharma, T. Gardenr, & D. Begbie (Eds.), *Approaches to Water Sensitive Urban Design* (1st ed.).

Cabanek, A., & Newman, P. (2016). Biophilic urban regeneration: can biophilics be a land value capture mechanism? In C. A. Brebbia, S. S. Zubi, & A. S. Hassan (Eds.), *WIT Transactions on Ecology and the Environment. Sustainable Development and Planning* (Issue 210, pp. 65–78). https://doi.org/10.2495/SDP160061

CABE. (2011). *Cheonggyecheon Restoration Project*. https://webarchive.nationalarchives.gov.uk/20110118114000/http://www.cabe.org.uk/case-studies/cheonggyecheon-restoration-project/description

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., MacE, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. In *Nature* (Vol. 486, Issue 7401, pp. 59–67). Nature Publishing Group. https://doi.org/10.1038/nature11148

Carmona, M. (2019). Principles for public space design, planning to do better. *Urban Design International*, *24*(1), 47–59. https://doi.org/10.1057/s41289-018-0070-3

Chapman, A. D. (2009). *Number of Living Species in Australia and the World*.

Church, S. P. (2015). Exploring Green Streets and rain gardens as instances of small scale nature and environmental learning tools. *Landscape and Urban Planning*, *134*, 229–240. https://doi.org/10.1016/j.landurbplan.2014.10.021

City of Bayswater. (n.d.). *Building Bayswater. Engage Bayswater*. Retrieved November 26, 2020, from https://engage.bayswater.wa.gov.au/30356/widgets/178010/documents/72248

City of Berkeley. (2012). *Downtown Area Plan*. https://www.cityofberkeley.info/dap/

City of Fremantle. (n.d.). *Land and nature*. Retrieved November 26, 2020, from https://www.fremantle.wa.gov.au/one-planet/land-and-nature

City of South Perth. (2019). *New seedlings to represent Noongar seasons*. https://southperth.wa.gov.au/about-us/news-and-publications/news-and-public-notices/news-detail/2019/08/14/new-seedlings-to-represent-noongar-seasons

Coffey, B., Bush, J., Mumaw, L., de Kleyn, L., Furlong, C., & Cretney, R. (2020). Towards good governance of urban greening: insights from four initiatives in Melbourne, Australia. *Australian Geographer*, *51*(2), 189–204. https://doi.org/10.1080/00049182.2019.1708552

Collard, L., Harben, S., & Berg, S. van den. (2004). *Nidja Beeliar Boodjar Noonookurt Nyininy: A Nyungar interpretive history of the use of Boodjar (country) in the vicinity of Murdoch University*.

Connop, S., & Nash, C. (2018). *Blandscaping that Erases Local Ecological Diversity*. The Nature of Cities. https://www.thenatureofcities.com/2018/01/09/blandscaping-erases-local-ecological-diversity/

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., & Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260. https://doi.org/10.1038/387253a0

Cox, D. T. C., Hudson, H. L., Shanahan, D. F., Fuller, R. A., & Gaston, K. J. (2017). The rarity of direct experiences of nature in an urban population. *Landscape and Urban Planning*, *160*. https://doi.org/10.1016/j.landurbplan.2016.12.006

CRC for Water Sensitive Cities. (2017). *White Gum Valley. A waterwise way of living*.

Cruz, S. S., Roskamm, N., & Charalambous, N. (2018). Inquiries into public space practices, meanings and values. *Https://Doi.Org/10.1080/13574809.2018.1525289*, *23*(6), 797–802. https://doi.org/10.1080/13574809.2018.1525289

Dallimer, M., Irvine, K. N., Skinner, A. M. J., Davies, Z. G., Rouquette, J. R., Maltby, L. L., Warren, P. H., Armsworth, P. R., & Gaston, K. J. (2012). Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness. *BioScience*, *62*(1), 47–55. https://doi.org/10.1525/bio.2012.62.1.9

Daniels, P., El Baghdadi, O., Desha, C., & Matthews, T. (2020). Evaluating net community benefits of integrating nature within cities. *Sustainable Earth 2020 3:1*, *3*(1), 1–15. https://doi.org/10.1186/S42055-020-00025-2

David, J., & Hammond, R. (2011). *High Line: The Inside Story of New York City's Park in the Sky*. Farrar Straus Giroux.

Davies, C., & Lafortezza, R. (2017). Urban green infrastructure in Europe: Is greenspace planning and policy compliant? *Land Use Policy*, *69*, 93–101. https://doi.org/10.1016/j.landusepol.2017.08.018

de Leeuw, E., Tsouros, A. D., Dyakova, M., & Green, G. (2014). *Healthy cities. Promoting health and equity-evidence for local policy and practice. Summary evaluation of Phase V of the WHO European Healthy Cities Network*.

Dempster, H. E. (2002). Weeds or wild flowers. In H. Spafford Jacob, J. Dood, J. Moore, H. S. Jacob, & J. H. Moore (Eds.), *Thirteenth Australian Weeds Conference papers & Proceedings* (pp. 685–688). RG and FJ Richardson.

Department of Water and Environmental Regulations. (2007). *Stormwater Management Manual for Western Australia*. https://www.water.wa.gov.au/urban-water/urban-development/stormwater/stormwater-management-manual

Desha, C., Reeve, A. C., Newman, P., & Beatley, T. (2016). Urban nature for resilient and liveable cities. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/SASBE-02-2016-0003

Downton, P., Jones, D., Zeunert, J., & Roös, P. (2017). Biophilic Design Applications: Putting Theory and Patterns into Built Environment Practice. *KnE Engineering*, *2*(2), 59. https://doi.org/10.18502/keg.v2i2.596

Duncan, D. T., Kawachi, I., White, K., & Williams, D. R. (2013). The Geography of Recreational Open Space: Influence of Neighborhood Racial Composition and Neighborhood Poverty. *Journal of Urban Health*, *90*(4), 618–631. https://doi.org/10.1007/s11524-012-9770-y

Dunnett, N., & Kingsbury, N. (2008). *Planting Green Roofs and Living Walls* (2nd ed.). Timber Press.

Duxbury, N., Hosagrahar, J., & Pascual, J. (2016). *Why must culture be at the heart of sustainable urban development?*

el-Baghdadi, O., & Desha, C. (2017). Conceptualising a biophilic services model for urban areas. *Urban Forestry and Urban Greening*, *27*. https://doi.org/10.1016/j.ufug.2016.10.016

Elmqvist, T., & Mcdonald, R. I. (2013). *Urbanization, Biodiversity and Ecosystem Services : Challenges and Opportunities. A Global Assessment* (T. Elmqvist, M. Fragkias, G. Julie, G. Burak, M. Peter, M. Robert, P. Susan, S. Maria, S. Marte, S. Karen, & W. Cathy, Eds.). Springer Open.

European Commission. (2011). *Our life insurance, our natural capital: an EU biodiversity strategy to 2020*.

European Parliament. (2016). *Mid-term review of the EU's Biodiversity Strategy*.

Fink, H. S. (2016). Human-nature for climate action: Nature-based solutions for urban sustainability. *Sustainability (Switzerland)*, *8*(3). https://doi.org/10.3390/su8030254

Francis, M. (1999). *A Case Study Method for Landscape Architecture*.

Frenkel, A. (2004). The potential effect of national growth-management policy on urban sprawl and the depletion of open spaces and farmland. *Land Use Policy*, *21*(4), 357–369. https://doi.org/10.1016/j.landusepol.2003.12.001

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, *3*(4), 390–394. https://doi.org/10.1098/rsbl.2007.0149

Gammage, B. (2012). *The Biggest Estate on Earth*. Allen & Unwin.

Gehl, J. (2010). *Cities for People*. Island Press.

Gehl, J. (2011). *Life Between Buildings: Using Public Space*. Island Press.

Gore, T., Ozdemiroglu, E., Eadson, W., Gianferrara, E., & Phang, Z. (2013). *Green Infrastructure's contribution to economic growth : a review*.

Graves Lanfer, A., & Taylor, M. (n.d.). *Immigrant Engagement in Public Open Space: Strategies for the New Boston*.

Grose, M. J., & Hedgcock, D. (2006). Designs for Stormwater Disposal in Public Open Space: An Ecological Assessment of Current Practices in Western Australia. *1st Australian National Hydropolis Conference in Perth*, *April*, 1–20.

Hall, T. (2010). *The Life and Death of the Australian Backyard*. CSIRO.

Hasluck, A. (1955). *Georgiana Molloy: Portrait with Background*. Oxford University Press.

Hazenberg, R., & Bajwa-Patel, M. (2014). *A review of the impact of waterway restoration*.

Hes, D., & Du Plessis, C. (2015). *Designing for Hope: Pathways to Regenerative Sustainability*. Routlege.

Hobbs, H., & Williams, G. (2018). The Noongar Settlement: Australia's First Treaty. *Sydney Law Review*, *40*(1), 1–39.

Hoffman, N., Brown, A., Brown, J. (Orchid enthusiast), & Scott Print. (2019). *Orchids of South-West Australia* (4th ed.). Orchids WA.

Hopper, S. D., & Gioia, P. (2004). The Southwest Australian floristic region: Evolution and conservation of a global hot spot of biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, *35*, 623–650. https://doi.org/10.1146/annurev.ecolsys.35.112202.130201

Hui, S. C. M., & Yan, L. T. (2016). Energy saving potential of green roofs in university buildings. *Joint Symposium 2016: Building a Smarter City via Latest Technologies*, *22 November*, 13.

Hunt, J., Altman, J. C., & May, K. (2009). *Social Benefits of Aboriginal Engagement in Natural Resource Management* (60/2009).

IPBS. (2019). Nature's Dangerous Decline 'Unprecedented' Species Extinction Rates 'Accelerating.' *Media Release*.

Jacobs, J. (1961). *The Death and Life of Great American Cities*. Random House.

Jones, D. S., Choy, D. L., Tucker, R., Heyes, S., Revell, G., & Bird, S. (2018). *Indigenous Knowledge in The Built Environment. A Guide for Tertiary Educators*.

Jones, D., Zeunert, J., Roös, P., Downton, P., & Zeunert, J. (2017). *Biophilic Design Applications: Putting Theory and Patterns into Built Environment*. https://doi.org/10.18502/keg.v2i2.596

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2). https://doi.org/10.5751/ES-08373-210239

Kaplan, Rachel., & Kaplan, S. (1989). *The experience of nature : a psychological perspective*. Cambridge University Press.

Kellert, S. R. (2012). *Birthright : people and nature in the modern world*. Yale University Press.

Kellert, S. R. (2016a). Biophilia and biomimicry: evolutionary adaptation of human versus nonhuman nature. *Intelligent Buildings International*, *8*(2). https://doi.org/10.1080/17508975.2014.902802

Kellert, S. R. (2016b). Biophilic urbanism: the potential to transform. *Smart and Sustainable Built Environment*, *5*(1). https://doi.org/10.1108/SASBE-10-2015-0035

Kellert, S. R. (2018). *Nature by design: The practice of biophilic design*. Yale University Press.

Kellert, S. R., & Calabrese, E. (2015). *The Practice of Biophilic Design*.

Kellert, S. R., Heerwagen, J., & Mador, M. (2008). *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life* (S. Kellert, J. Heerwagen, & M. Mador, Eds.). John Wiley & Sons. https://doi.org/10.1680/udap.11.00035

Kirk, E. (2017, November 1). Cornerstone Christian College Dunsborough. Six Season Garden. *Busselton Mail*.

Kitchen, T. (2000). Building the 21st century home: The sustainable urban neighbourhood. *Urban Studies*.

Knapp, C. (2008). *Making Multicultural Places*. https://www.pps.org/article/multicultural-places

Kostof, S. (1999). *The City Shaped: Urban patterns and meanings thorugh history*. Thames & Hudson.

Landcorp. (2018). *One Planet Action Plan 2018 Review*.

Landscape Architecture Foundation. (n.d.). *Cheonggyecheon Stream Restoration Project. Landscape Performance Series*. Retrieved November 15, 2020, from https://www.landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration

Lee, J. Y., & Anderson, C. D. (2013). The Restored Cheonggyecheon and the Quality of Life in Seoul. *Journal of Urban Technology*, *20*(4), 3–22. https://doi.org/10.1080/10630732.2013.855511

Levere, M. (2014). *The High Line Park and Timing of Capitalization of Public Goods*. http://docplayer.net/42473681-The-high-line-park-and-timing-of-capitalization-of-public-goods.html

Liebelt, V., Bartke, S., & Schwarz, N. (2018). Hedonic pricing analysis of the influence of urban green spaces onto residential prices: the case of Leipzig, Germany. *European Planning Studies*, *26*(1), 133–157. https://doi.org/10.1080/09654313.2017.1376314

Lines, W. J. (1994). *An all consuming passion : origins, modernity, and the Australian life of Georgiana Molloy*. Allen & Unwin.

Littke, H. (2016). Becoming biophilic. *Smart and Sustainable Built Environment*, *5*(1), 15–24. https://doi.org/10.1108/SASBE-10-2015-0036

Louv, R. (2005). *Last child in the woods. Saving our children from nature-deficit disorder*. Atlantic Books.

Lovell, S. T., & Taylor, J. R. (2013). Supplying urban ecosystem services through multifunctional green infrastructure in the United States. *Landscape Ecology*, *28*(8), 1447–1463. https://doi.org/10.1007/s10980-013-9912-y

Low, S. M., Taplin, D., & Scheld, S. (2005). *Rethinking urban parks : public space & cultural diversity*. The University of Texas Press.

Lundholm, J. T. (2015). Green roof plant species diversity improves ecosystem multifunctionality. *Journal of Applied Ecology*, *52*(3), 726–734. https://doi.org/10.1111/1365-2664.12425

Maller, C., Townsend, M., Henderson-Wilson, C., Pryor, A., Prosser, L., & Moore, M. (2008). *Healthy parks, healthy people. The health benets of contact with nature in a park context. A review of relevant literature* (2nd ed.).

Mang, P., & Reed, B. (2012). Regenerative development and design. In R. Meyers (Ed.), *Encyclopedia of Sustainability Science and Technology*. https://doi.org/10.1007/978-1-4419-0851-3

Marinelli, J. (2021). *Urban Refuge: How Cities Can Help Solve the Biodiversity Crisis*. https://e360.yale.edu/features/urban-refuge-how-cities-can-help-solve-the-biodiversity-crisis

Masson-Delmotte, V., Zhai, P., Portner, H. O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Pidcock, R., Connors, S., Matthews, J. B. R., Chen, Y., Zhou, X., Gomis, M. I., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (2018). *IPPC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global*. https://doi.org/10.1016/j.oneear.2019.10.025

Matan, A., & Newman, P. (2016). *People Cities*. Island Press.

Matthews, T., Lo, A. Y., & Byrne, J. A. (2015). Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape and Urban Planning*, *138*. https://doi.org/10.1016/j.landurbplan.2015.02.010

McDonald, R. I., Beatley, T., & Elmqvist, T. (2018). The green soul of the concrete jungle: the urban century, the urban psychological penalty, and the role of nature. *Sustainable Earth 2018 1:1*, *1*(1), 1–13. https://doi.org/10.1186/S42055-018-0002-5

McIntosh, J., Trubka, R., & Newman, P. (2014). Can value capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia. *Transportation Research Part A: Policy and Practice*, *67*, 320–339. https://doi.org/10.1016/j.tra.2014.07.008

McKemey, M., Ens, E., Rangers, Y. M., Costello, O., & Reid, N. (2020). Indigenous knowledge and seasonal calendar inform adaptive savanna burning in northern Australia. *Sustainability (Switzerland)*, *12*(3), 1–18. https://doi.org/10.3390/su12030995

Mell, I. C. (2019). Selling Nature: Aligning Green Infrastructure Principles with the Funding of Urban Landscapes. *Cities*, *6*, 32. https://doi.org/10.7275/jr0q-6q59

Mell, I. C., Henneberry, J., Hehl-Lange, S., & Keskin, B. (2013). Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. *Urban Forestry and Urban Greening*, *12*(3), 296–306. https://doi.org/10.1016/j.ufug.2013.04.006

Mell, I. C., Henneberry, J., Hehl-Lange, S., & Keskin, B. (2016). To green or not to green: Establishing the economic value of green infrastructure investments in The Wicker, Sheffield. *Urban Forestry and Urban Greening*, *18*. https://doi.org/10.1016/j.ufug.2016.06.015

Miles, M., & Huberman, M. (1994). *Qualitative Data Analysis: An Expanded Sourceboook* (2nd ed.). Sage Publications Ltd.

Miller, K. R. (2001). Bioregional Planning and Biodiversity Conservation. In S. Stolton & N. Dudley (Eds.), *Partnerships for Protection: New Strategies for Planning and Management for Protected Areas* (Vol. 25, Issue 3, pp. 41–42). Eartscan Publlications Ltd. https://doi.org/10.1016/S0165-0203(01)00017-4

Mills, A. J., Durepos, G., & Wiebe, E. (2012). Multiple-Case Designs In: Encyclopedia of Case Study Research. In *Encyclopedia of Case Study Research*. SAGE Publications . https://doi.org/10.4135/9781412957397

Mumford, L. (1961). *The City in History: Its Origins, Its Transformations, and Its Prospects*. Secker and Warburg.

Nannup, N. (2006). *Moondang-ak Kaaradjiny*. Batchelor Press.

Nechyba, T. J., & Walsh, R. P. (2004). Urban sprawl. *Journal of Economic Perspectives*, *18*(4), 177–200. https://doi.org/10.1257/0895330042632681

Newman, P. (2014). Biophilic urbanism: a case study on Singapore. *Australian Planner*, *51*(1), 47–65. https://doi.org/10.1080/07293682.2013.790832

Newman, P. (2015). Transport infrastructure and sustainability: a new planning and assessment framework. *Smart and Sustainable Built Environment*, *4*(2), 140–153. https://doi.org/10.1108/SASBE-05-2015-0009

Newman, P. (2016). Sustainable urbanization: four stages of infrastructure planning and progress. *Journal of Sustainable Urbanization, Planning and Progress*, *1*(1), 3–10. https://doi.org/10.18063/jsupp.2016.01.005

Newman, P., Beatley, T., & Boyer, H. (2017a). Build Biophilic Urbanism in the City and Its Bioregion. In *Resilient Cities*. https://doi.org/10.5822/978-1-61091-686-8_6

Newman, P., Beatley, T., & Boyer, H. (2017b). *Resilient cities: Overcoming fossil fuel dependence*. https://doi.org/10.5822/978-1-61091-686-8

Newman, P., Davies-Slate, S., & Jones, E. (2018). The Entrepreneur Rail Model: Funding urban rail through majority private investment in urban regeneration. *Research in Transportation Economics*, *67*, 19–28. https://doi.org/10.1016/j.retrec.2017.04.005

Newman, P., & Jennings, I. (2008). *Cities as Sustainable Ecosystems. Principles and Practices as*. Island Press.

Norman, B., Newman, P., & Steffen, W. (2021). Apocalypse now: Australian bushfires and the future of urban settlements. *Npj Urban Sustainability*, *1*(1), 1–9. https://doi.org/10.1038/s42949-020-00013-7

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning*, *134*. https://doi.org/10.1016/j.landurbplan.2014.10.018

Pascoe, B. (2018). *Dark Emu*. Magabala Books.

Pearce, F. (2019). Why Green Pledges Will Not Create the Natural Forests We Need - Yale E360. *Yale Environment 360*.

Pedersen Zari, M. (2017). What makes a city “biophilic”? Observations and experiences from the Wellington Nature Map project. In M. Aurel (Ed.), *Back to the future: The next 50 years, 51st International Conference of the Architectural Science Association 2017* (pp. 1–10). The Architectural Science Association and Victoria University of Wellington.

Pedersen Zari, M. (2019). Understanding and designing nature experiences in cities: a framework for biophilic urbanism. *Cities & Health*. https://doi.org/10.1080/23748834.2019.1695511

Pezzoli, K., & Leiter, R. A. (2016). Creating healthy and just bioregions. *Reviews on Environmental Health*, *31*(1), 103–109.

Prudencio, L., & Null, S. E. (2018). Stormwater management and ecosystem services: a review. *Environmental Research Letters*, *13*(3), 033002. https://doi.org/10.1088/1748-9326/aaa81a

Reeve, A., Desha, C., Hargroves, C., Newman, P., & Hargreaves, D. (2013). A Basis for Inquiry into Policy Considerations for Increasing the Application of Biophilic Urbanism. In S. Rauch, G. Morrison, S. Norra, & N. Schleicher (Eds.), *Urban Environment* (pp. 143–151). Springer Netherlands. https://doi.org/10.1007/978-94-007-7756-9_12

Reeve, A., Hargroves, C., Desha, C., & Newman, P. (2012). Informing healthy building design with biophilic urbanism design principles: a review and synthesis of current knowledge and research. *Healthy Buildings 2012 - 10th International Conference of The International Society of Indoor Air Quality and Climate*.

Reil, A., & Balenciaga, I. (2019). *Beyond re-naturing cities : Integrating social justice and health equity in urban greening*.

Robertson, F., Nannup, N., Stasiuk, G., & Hopper, S. (2017). *Nyoongar Boodja: Koomba Bardip Kooratan*. Batchelor Press.

Rottle, N., & Yocom, K. (2011). *Basics Landscape Architecture 02: Ecological Design* (1st ed.). AVA Publishing.

Salingaros, N. A. (2010). Life and the Geometry of the Environment. *Harvard University’s Center for Hellenic Studies*, *2*, 1–19.

Salingaros, N. A. (2015). *Biophilia & Healing Environments: Healthy Principles for Designing the Built World*. Terrapin Bright Green.

Salingaros, N. A. (2019). The Biophilic Healing Index Predicts Effects of the Built Environment on Our Wellbeing. *Biourbanism*, *8*(1), 13–34.

Sanderson, E. W., Walston, J., & Robinson, J. G. (2018). From Bottleneck to Breakthrough: Urbanization and the Future of Biodiversity Conservation. In *BioScience* (Vol. 68, Issue 6, pp. 412–426). Oxford University Press. https://doi.org/10.1093/biosci/biy039

Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Esocystem Services*, *12*, 1–15. https://doi.org/10.1016/j.ecoser.2014.12.007

SBEnrc. (2011). *Considering the Application of Biophilic Urbanism*.

SBEnrc. (2012). *Can biophilic urbanism deliver strong economic and social benefits in cities?*

Schwarz, N., Moretti, M., Bugalho, M. N., Davies, Z. G., Haase, D., Hack, J., Hof, A., Melero, Y., Pett, T. J., & Knapp, S. (2017). Understanding biodiversity-ecosystem service relationships in urban areas: A comprehensive literature review. *Ecosystem Services*, *27*, 161–171. https://doi.org/10.1016/j.ecoser.2017.08.014

Seddon, G. (1972). *Sense of Place. A response to an Environment, the Swan Coastal Plain, Western Australia*. University of Western Australia Press.

Seddon, G. (2005). *The Old Country: Australian Landscapes, Plants and People*. Cambridge University Press.

Seddon, G., & Ravine, D. (1986). *A city and its setting : images of Perth, Western Australia*. Fremantle Arts Centre Press.

Selin, H. (2003). *Nature Across Cultures : Views of Nature and the Environment in Non-Western Cultures*. Springer Netherlands.

Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Dean, J., Barber, E., & Fuller, R. A. (2016). Health Benefits from Nature Experiences Depend on Dose. *Scientific Reports*, *6*(2), 1–10. https://doi.org/10.1038/srep28551

Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., & Fuller, R. A. (2015). What is the role of trees and remnant vegetation in attracting people to urban parks? *Landscape Ecology*, *30*(1), 153–165. https://doi.org/10.1007/s10980-014-0113-0

Shire of York. (n.d.). *Ballardong Noongar Six Seasons Garden Walk*. Retrieved August 27, 2020, from https://www.york.wa.gov.au/museum/visit/museum-ballardong-noongar-six-seasons-garden-walk.aspx

Shwartz, A., Turbé, A., Simon, L., & Julliard, R. (2014). Enhancing urban biodiversity and its influence on city-dwellers: An experiment. *Biological Conservation*, *171*, 82–90. https://doi.org/10.1016/j.biocon.2014.01.009

Simaika, J. P., & Samways, M. J. (2010). Biophilia as a Universal Ethic for Conserving Biodiversity. *Conservation Biology*, *24*(3), 903–906.

Söderlund, J. (2019). The Emergence of a New Social Movement: Biophilic Design. In *The Emergence of Biophilic Design* (pp. 1–11). Springer Nature. https://doi.org/10.1007/978-3-030-29813-5_1

Stake, R. E. (2005). *Multiple case study analysis*. Guilford Press.

Steiner, F. R., Thompson, G. F., & Carbonell, A. (Eds.). (2016). *Nature and Cities*. Lincoln Institute of Land Policy.

Stockmann, E. (2018). *Personal communication* (p. 26 June).

Talen, E. (2008). *Design for Diversity*. Architectural Press.

Taylor, D. E. (2018). Racial and Ethnic Differences in Connectedness to Nature and Landscape Preferences Among College Students.

Https://Home.Liebertpub.Com/Env, *11*(3), 118–136. https://doi.org/10.1089/ENV.2017.0040

The Convention on Biological Diversity. (2020). *Global Biodiversity Outlook 5*.

The Nature Conservancy. (2018). *Nature in the Urban Century. A global assessment of where and how to conserve nature for biodiversity and human wellbeing.* https://www.nature.org/en-us/what-we-do/our-insights/perspectives/nature-in-the-urban-century/?vu=r.d_urbannature100

Totaforti, S. (2020). Emerging biophilic urbanism: The value of the human-nature relationship in the urban space. *Sustainability (Switzerland)*, *12*(13). https://doi.org/10.3390/su12135487

Town of Bassendean. (n.d.). *Oridinary Council Agenda 27 May 2020*. Retrieved November 26, 2020, from https://www.bassendean.wa.gov.au/council-meetings/ordinary-council-meeting/ordinary-council-meeting/408/documents/attachments-1-to-8.pdf

Triman, J. (2013). *New urban rail parks seek to improve on High Line*. Biophilic Cities. https://www.biophiliccities.org/urban-rivers-of-life/

Tucker, R., Low Choy, D., Heyes, S., Revell, G., & Jones, D. (2018). Re-casting terra nullius design-blindness: better teaching of Indigenous Knowledge and protocols in Australian architecture education. *Int J Technol Des Educ*, *28*, 303–322. https://doi.org/10.1007/s10798-016-9389-5

Turner, A., Wilson, K., & Wilks, J. L. (2017). Aboriginal Community Engagement in Primary Schooling: Promoting Learning through a Cross-Cultural Lens. *Australian Journal of Teacher Education*, *42*(11), 42. https://doi.org/10.14221/ajte.2017v42n11.7

UN HABITAT. (2009). State of the World's cities. Harmonious cities. In *Earthscan*.

United Nations. (1987). *Report of the World Commission on Environment and Development: Our Common Future*. https://doi.org/10.9774/gleaf.978-1-907643-44-6_12

Vargas-Hernández, J. G., & Zdunek-Wielgołaska, J. (2020). Urban green infrastructure as a tool for controlling the resilience of urban sprawl. *Environment, Development and Sustainability 2020 23:2*, *23*(2), 1335–1354. https://doi.org/10.1007/s10668-020-00623-2

WA Parks Foundation. (2021). *Muminbulah Wilak – ATCO's six seasons garden*. https://www.ourwaparks.org.au/muminbulah-wilak-atcos-six-seasons-garden/

Wall, D. H., Nielsen, U. N., & Six, J. (2015). Soil biodiversity and human health. *Nature*, *528*(7580), 69–76. https://doi.org/10.1038/nature15744

Wansborough, M., & Mageean, A. (2000). The role of urban design in cultural regeneration. *Journal of Urban Design*, *5*(2), 181–197. https://doi.org/10.1080/713683962

Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence

from salivary cortisol patterns. *Landscape and Urban Planning*, *105*(3), 221–229. https://doi.org/10.1016/j.landurbplan.2011.12.015

Watkins, B. (2017). *York Bushland Garden*. Wildflower Society WA.

WEF. (2020). *Nature Risk Rising : Why the Crisis Engulfing Nature Matters for Business and the Economy* (Issue January).

Wheatbelt NRM. (2016). *Establishing the 'Six Seasons' Garden*. https://www.wheatbeltnrm.org.au/whats-happening/news/aboriginal-nrm/establishing-'six-seasons'-garden

Wijesooriya, N., & Brambilla, A. (2020). Bridging biophilic design and environmentally sustainable design: A critical review. In *Journal of Cleaner Production* (p. 124591). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2020.124591

Wiktorowicz, J., Babaeff, T., Breadsell, J., Byrne, J., Eggleston, J., & Newman, P. (2018). WGV: An Australian urban precinct case study to demonstrate the 1.5 °C agenda including multiple SDGs. *Urban Planning*, *3*(2), 64–81. https://doi.org/10.17645/up.v3i2.1245

Wilson, B., & Chakraborty, A. (2013). The environmental impacts of sprawl: Emergent themes from the past decade of planning research. *Sustainability (Switzerland)*, *5*(8), 3302–3327. https://doi.org/10.3390/su5083302

Wilson, E. O. (1984). *Biophilia*. Harvard University Press.

Wilson, E. O., & Kellert, S. R. (1993). *The Biophilia Hypothesis*. Island Press.

Wolff, M., & Haase, D. (2019). Mediating sustainability and liveability-turning points of green space supply in European cities. *Frontiers in Environmental Science*, *7*(5). https://doi.org/10.3389/fenvs.2019.00061

Wong, T. H. F., & Breen, P. F. (1998). *Managing Urban Stormwater Using Constructed Wetlands*.

Wooltorton, S., Collard, L., & Horwitz, P. (2019). Layers of meanings in our landscapes Hiding in full view. In M. Ellis (Ed.), *Critical Global Semiotics* (1st ed.). Routledge.

Wooltorton, S., White, P., Palmer, M., & Collard, L. (2020). Learning Cycles: Enriching Ways of Knowing Place. *Australian Journal of Environmental Education*. https://doi.org/10.1017/aee.2020.15

World Economic Forum. (2020). *New Nature Economy Report II. The future of nature and business*. https://www.weforum.org/reports/new-nature-economy-report-ii-the-future-of-nature-and-business

World Health Organization. (2018). *Urban green spaces and health - a review of evidence (2016)*. World Health Organization.

Yazdani, N., & Lozanovska, M. (2014). Representation of multiculturalism in urban green spaces: a review of immigrants' experiences in Australia. *UHPH 2014 : Landscapes and Ecologies of Urban and Planning History : Proceedings of the 12th Australasian Urban History Planning History Conference*, 851–864.

Yeon Hwang, K. (2004). *Restoring Cheonggyecheon Stream in the Downtown Seoul*.

Yin, R. K. (2009). *Case Study Research: Design and Methods* (4th ed.). SAGE Publications.

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). SAGE Publication, Inc.

Appendix A: Interview Questionnaire 1

Interview Questions:

Note: Before starting the interview, please read the Participant Info Sheet and Consent Form-Interview provided. Please sign the Consent Form before the interview. Answering the questions is not obligatory. You can stop the interview at any time without any consequences.

Design

1. Are you familiar with the concept of biophilia and biophilic design?
2. What is your (your team) design methodology?
3. In your opinion, what is the perception of biophilic design in a standardised design process?

Business Case

4. How can a biophilic project be financed?
5. How do you estimate the costs and benefits of a biophilic project?
6. What are the main barriers to mainstreaming biophilic design?

Procurement

7. Can you briefly describe the procurement process?

Execution of project

8. How does your execution process differ from a usual process?
9. What measures are taken to ensure the execution of a project complies with the principles of biophilic design?

Evaluation

10. What criteria do you apply when evaluating a completed project?
11. How is the success of the project measured?

Appendix B: Interview Questionnaire 2

The project title: *Biophilic regeneration of stormwater infiltration basins in Western Australia. Case studies of White Gum Valley and the Green Swing.*

Interview Questions:

Note: Before starting the interview, please read the Consent Form-Interview provided. Please sign the Consent Form before the interview. Answering the questions is not obligatory. You can stop the interview at any time without any consequences.

1. Where did the idea of repurposing the existing sump come from?
2. Who were the actors (collaborators) involved in this project?
3. What were the drivers and values motivating stakeholders to reinvent the sump?
4. What were the investors' expectations from this project?
5. Can you explain the process from the initiation to completion?
6. Was the local government supportive during the process?
7. Did you receive any support from any private or public agencies?
8. What difficulties or obstacles did you come across during different stages of the project?
9. What were the risks associated with the development of this project?
10. How did the local community react to this project?
11. The benefits coming from this project? Any environmental, social or financial benefits?
12. Was there a business case done for the sump garden?
13. How was this project financed?
14. Did you receive any financial support from the local government?
15. What was the total cost of the project?
16. How is the sump used now?
17. What was the important lesson you learnt from this project?
18. Has the idea of reinventing the sump been replicated in other developments in Perth?

Appendix C: Publication 1

Publication 1

Cabanek, A. & Newman, P. (2016). Biophilic urban regeneration: can biophilics be a land value capture mechanism? In C.A. Brebbia, S.S. Zubir & A.S. Hassan (Eds.), WIT Transactions on Ecology and the Environment. Sustainable Development and Planning (pp. 65-78). Doi: 10.2495/SDP160061

Biophilic urban regeneration: can biophilics be a land value capture mechanism?

A. Cabanek[1] & P. Newman[1]
[1]Curtin University Sustainability Policy Institute, Australia.

Abstract

There is strong evidence for environmental, economic and social benefits derived through the applied methodology of biophilic design. Early data on the impacts of biophilics provides evidence for the significant increase in urban land and property prices as well as the public value of ecosystem services. The need for urban regeneration has been proposed for cities to prevent the impact of urban sprawl to create more sustainable outcomes in energy, water and waste. To make urban regeneration happen requires an increase in urban amenities so that investment becomes worthwhile. This paper attempts to examine how biophilic elements of different scales can be used in urban regeneration and whether it can assist the regenerative city agenda. The land value capture mechanism has been proved successful in many North American cities. Through analysis of selected case studies, the paper demonstrates how the role of biophilics could be better implemented by governments and private investors as a core factor in creating urban regeneration projects.
Keywords: biophilia, biophilic design, urban regeneration, land value capture

1. Introduction

The principles of biophilic cities have been outlined in a number of publications and are increasingly being demonstrated around the world [1]. The value of any urban nature interaction has been assessed positively but the mainstreaming process remains elusive. Urban planners and designers have become increasingly aware of the economic benefits that urban greenery can create [1,2,3]. This paper suggests a possible funding mechanism to enable biophilic urbanism to be mainstreamed as a part of urban regeneration. The concept of land value capture started in the United States as a way of funding urban regeneration at local government level [4,5]. Because urban regeneration through street furniture, landscaping and urban infrastructure increases the value of properties, there is a consequent increase in local taxation returns through rates, land taxes and sales taxes. These increases can be estimated and used as a hypothecated fund to pay for the financing of the improvements. The method has been adapted for funding urban rail in the United States, the United Kingdom and Australia [4]. This paper examines whether land value capture could be used to fund the mainstreaming of biophilic urbanism projects.

2. Methodology

Literature relating to biophilic design and the valuation of biophilic elements was sourced from bibliographic databases, university libraries and the internet. A

number of case studies were selected to investigate the relationship between real estate value and green and blue infrastructure to prove the argument that biophilic elements of different scales enable urban regeneration to become attractive for private and public investments.

The analysis of selected case studies provides an insight into the benefits of thoughtful and strategic implementation of green infrastructure in commercial and private housing developments [6]. The methodology most commonly used to estimate the impact of green infrastructure on real estate value is called hedonic pricing. This methodology is often used in cases where non-market environmental goods and services such as air and water quality, and proximity to green spaces are considered value enhancers for adjacent land and properties. Often the valuation is based on comparing properties that differ with respect to their distance from environmental amenities such as parks, wetlands, recreational sites, open space or communal gardens [7].

3. Biophilia

The term 'biophilia' was first used by psychologist Erich Fromm to describe humans' natural affiliation and 'love for nature' [1]. In 1980s it was adopted by world-renowned biologist, Edward O. Wilson, when he realized the negative consequences of ongoing separation of people from nature. Wilson described biophilia as "the affiliation of human beings to other living organisms" [1,8]. According to Kellert, biophilia is a missing link in sustainable design. Kellert [9] provides background theory for biophilic design, "a design approach in the built environment". Kellert and Wilson (1993) stated that the main objective of biophilic design is to be "the deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and processes … into the design of the built environment" [10]. Biophilia, as a background methodology, considers the multidimensional and interdependent complexities of urban systems and infrastructure to provide restorative, regenerative spaces capable of mitigating the destructive effects of the urban heat island effect, storm water, air pollution, electricity demand and biodiversity loss [3].

3.1 Biophilic urbanism

Beatley [1] described it simply as biophilia on an urban scale. Biophilic urbanism is a relatively new term which also can be explained as "the principle of harnessing natural features as functional design elements, particularly in buildings" [11]. It has also been described as an approach in "bringing nature to our doorsteps" by intentionally designing the outdoors to reconnect people with flora and fauna [3]. The main role of biophilic urbanism is to create an environment that is "psycho-physiologically and cognitively restorative" [12]. This is to reverse the trend of downgrading natural ecosystems from city spaces due to the increasing density of the built environment and instead enabling structures to become regenerative to natural ecosystems [13].

3.2 Biophilic urban design

Biophilic urban design aims to create healthy, attractive and interconnected urban environments such as green corridors, green belts, networks of urban 'living architecture' using vegetated walls and roofs [1], rivers and canals as potential sites for new habitats and biodiversity hotspots. Biophilic design promotes development of educational facilities, and the design of infrastructure in such a way that encourages interaction with nature, whilst engaging inquisitive minds of all ages in their natural environment.

To achieve meaningful and beneficial biophilic design, a number of principles have been proposed [9]: the experience of nature in the built environment should be repeated, ongoing and sustained; the design should consider human adaptation to the natural world that over thousands of years have advanced people's health and wellbeing; attachment to particular ecological and cultural settings and places should result from design; positive interaction between people and nature should be created; connected, mutually reinforcing and integrated architectural solutions should result from the design.

Biophilic cities are different from green cities. In biophilic cities the emphasis is put on wellbeing and health, celebrating living forms and processes. Green city's main objectives are to reduce energy consumption, minimize environmental impact, and enhance environmental conservation [1].

3.3 How does landscape architectural design differ from biophilic design?

Biophilic design is a methodology which could and should be used by landscape architects and designers to create healthy, meaningful spaces. Landscape architects tend to design spaces embodying a client's vision of the place. There is pressure to create visually appealing places, but not necessarily restorative ones, neglecting rather than enhancing biodiversity and ecosystem services. Some designs end up producing non-living landscapes. This could be avoided by applying the principles of biophilic design to every project. The methodology of biophilia aims to create urban landscapes to become living systems [12].To design a living, restorative urban space, a landscape architect may consider using the fourteen patterns of biophilic design specified by Terrapin Bright Green [12]. The patterns observed in the natural environment can be used as the framework to apply biophilic design in the built environment. Each pattern aims to meet the health, social and economic priorities of the project owner at the same time providing solutions to the evolving needs of the ecosystems [14]. The fourteen design patterns are adaptable and replicable strategies for improving the usernature encounter that can be implemented under many circumstances [13].

4. Land value and biophilic urbanism

Some of the key environmental factors affecting property and land prices are greenery, surface water, noise impacts and landscape features. The main focus of this study is to establish how strongly biophilic elements impact the land and property value. The first part in this section examines the land value increase due to traditional green spaces. In the second part it will be shown how innovative biophilic structures, such as green walls, roofs and elevated parks, contribute to the increase of land and property values. The paper will then show how it is possible to capture this land value as a funding mechanism.

4.1 Urban green and blue infrastructure and its impact on property value

Crompton's [15] analysis of 30 case studies investigated the relationship between real estate value and proximity to parks; they confirmed the argument that urban green spaces contribute to higher property values. He estimated a 20 percent increase in the value of properties adjacent to park areas when assessing property value increases attributed to urban green spaces.

A study of 3000 properties in Philadelphia conducted by Watcher (2004) showed the effect that investing in green infrastructure has on property value. The author focused on converting vacant land into quality green spaces. The results suggested that turning a vacant lot into a green space could potentially increase surrounding properties value by 30 percent [16].

One of the flagship examples of restorative projects, resulting in a regeneration of a significant urban area, is Cheonggyecheon Stream Restoration Project in Seoul, South Korea. In 2001, the Mayor of Seoul proposed removing Cheonggye freeway and restore the Cheonggyecheon River in order to revitalize the area economically and restore the status of 'pride of Seoul' for the area. According to a survey conducted, the project proposal was supported by 79 percent of residents. Completed in September 2005, the project became a source of tremendous pride for Seoul [17]. The main economic benefits from the project feature a significant increase in the price of land by 30-50 percent for properties within 50 meters of the project, which doubled the increases in other parts of Seoul. The cost of the project was $380 million and the restoration has served as a catalyst for an estimated 22 trillion won ($1.98 billion) worth of capital investment in the Cheonggyecheon area redevelopment that would not have otherwise been invested. The case study is an example of successful urban regeneration where blue and green infrastructure become incentives for economic development [18].

Canalside regeneration project in Birmingham City Centre in the United Kingdom is another notable example. According to the study led by GHK in 2009, the net impact of the canalside development on property values was between £25.7 and £57.1 million [19]. In 2014, Birmingham became a member of Biophilic Cities Network. The city has committed to become green and sustainable and to enhance connections between health and nature. To achieve these objectives, the Green Living Spaces Plan was prepared by the city council. The most impressive project Birmingham has committed to is a creation of a network of rivers and streams which serve as a grid of trails and pathways for the citizens, as well as restoring their natural ecosystems.

The Birmingham canalside regeneration is an example of the impact of biophilic design on urban economic growth. The project has provided recreational and aesthetic ecosystem services as well as improving water quality in the rivers and canals.

4.2 Green roofs, walls and elevated parks and their impact on land/property value

In the report published by Smart Cities Research Centre [7], the properties with accessible green roofs are subject to 11 percent property value premium. Also, the

analysis of the properties featuring rooftop food gardens demonstrated an increase of 7 percent in property value. The adjacent properties could gain between 2 and 7 percent, and those who have views onto a green roof could potentially gain up to 4.5 percent of property value.

Research about the impact of green walls on property value is emerging. Green walls, also called vertical gardens, are an easily identifiable symbol of the sustainable building movement since they are visible and increase green area ratio in urban centres [20]. A report prepared by Peck & Associates [21] stated that in Toronto (Canada) property values increase 6-15 percent for buildings when they include green walls. Des Rosiers *et al* [22] estimated that a green wall could add 3.9 percent to a property value. This figure was based on the analysis of property data in Quebec (Canada). Also, the Growing Green Guide points to a green wall as a factor that could add value to any property but is lacking concrete examples and figures. Further research is needed to estimate the value green walls could add to properties in other countries.

One of the most successful urban regeneration projects featuring many aspects of biophilic design is the High Line - an elevated urban park in Manhattan (the United States). It was built in three phases between 2006 and 2014 on a neglected freight rail lane. The project was developed and promoted as an economic regeneration of an industrial area and has become one of the major tourist attractions in New York [1, 23]. The High Line project significantly lifted the value of surrounding properties, stimulated the commercial and residential property market resulting in an estimated $4 billion in private investment [1].

The idea of saving the freight area from demolition came from residents, who founded a not-for-profit organization, ‘Friends of the High Line”. Thanks to the successful marketing campaign launched by the organization, the general public became well informed about its potential and the significance of the proposed regeneration project. Supporters of the High Line, including some members of the city council, obtained significant funds to develop the project. ‘Friends of the High Line’ managed to raise $300 million from private investors to finance the completion of the project and the ongoing maintenance [23] on the basis that it would improve the value of their properties.

‘Friends of the High Line’ studied the potential economic gains for the freight line area. These studies projected how incremental tax revenues created by higher real estate values around the park would outweigh the costs.

Levere [24] assessed the High Line’s impact on house prices by looking at property sales and figures. The amount calculated was an impressive $100 million increase in property taxes that the city gained in 2010 alone. Compared with the overall cost of the project, the financial benefits generated by the High Line significantly outweighed the costs and the profits continue to raise revenue.

Factors that led to the successful execution of the project were, according to Ascher and Uffer [23]: the marketing campaign carried by ‘The Friends of the High Line’ and their celebrity supporters; political and federal support; the public-private partnership between ‘Friends of the High Line’ and the Government; the re-zoning and new regulations that allowed potential development to the area.

The High Line initiative shows an alternative way of funding green infrastructure projects, using projected tax revenues and other financial benefits to activate a

project. In case of the High Line, its popularity led other cities to try and replicate its success. Similar elevated greenways and linear parks have been planned for Chicago, Philadelphia, Atlanta and Rotterdam [25], proving that private and public investors are starting to recognize the value of urban regeneration using biophilics.

5. Policy implications

A number of cities around the world have developed and implemented policies to encourage and require structures as green walls and roofs to appear in new development projects [11]. Reports collected and reviews of case studies done by the research group SBErnc [3] project have shown that the cities focused mostly on outcomes than processes of achieving biophilic projects, reporting rather on the size of allocated budget and structures. The report produced by SBErnc points to the most important issues, which have to be resolved to overcome challenges and barriers in achieving desirable biophilic outcomes. These are: reducing political and financial risk and leveraging opportunities; creating policies, guidelines and programs appropriate to any city's circumstances.

In this paper, the authors propose implementing a mechanism of land value capture as one way of funding biophilic projects by private investors.

To encourage and facilitate design based on biophilic urbanism strategies in urban regeneration projects, local governments should consider alternative ways of financing new investments. The proposed land value capture mechanism has been successfully used in the United States, Canada, Japan and Hong Kong [4]. It has been founded on a principle that land value is determined by its intrinsic value plus any private investment that is enabled because of investment in infrastructure, economic development and population growth [26].

The land value capture mechanism focuses mainly on attracting necessary funds to finance a new development project. It has been successfully used to finance new rail developments. The mechanism estimates the increased value on land around urban rail. The projected additional value is used to fund rail systems [4, 26]. A similar approach could be used to fund biophilic urban projects: the land value capture mechanism could be used to calculate approximate land value increases and allocate the profits towards funding a biophilic urban infrastructure.

From the analysis of the selected case studies, it has clearly been shown that the increases in land values could be generated through a strategic design of the public amenities using the principles of biophilic urbanism. A local government can gain extra taxation revenues as a result of new development, without raising the existing rates [4]. These revenues can be forecast and included into future budgets as a means of paying for biophilic urban infrastructure costs up front.

It has been shown that urban greenery has the potential to uplift the value of land and adjacent properties. Therefore, it is likely that biophilic design principles informing strategic urban design may have the potential to further increase this value. Estimated financial gains increase by up to 50 percent as shown through the above analysis of selected case studies. The land value forecast could be used to attract capital to the project before it is built and by this way it can help to fund the project.

Extra land value could be added by introducing a biophilic design methodology to create healthy, environmentally responsible and regenerative green and blue infrastructure seamlessly woven into the built environment to enhance its economic value. Such a mechanism exists in Singapore where a green floor ratio is required to replace the floor plate of a building by 2 to 3 times the amount of greenery through green roofs, walls and balconies [27]. This innovation has become a major factor in the city's tourism and economic development.

A number of publications have shown that there is an emerging market in cities for biophilic urban regeneration, highlighting that homebuyers are choosing properties with close proximity to high quality urban open spaces. Furthermore, this increase in land value can be used to attract private and public investors to deliver new businesses in the area. New investments help to create vibrant neighbourhoods, indirectly lifting the value of all properties nearby.

This paper suggests that a government mechanism of land value capture can be used to create biophilic projects into the mainstream of urban policy.

References

[1] Beatley, T., *Biophilic Cities: Integrating Nature into Urban Design and Planning,* Island Press: Washington, 2010.

[2] Beatley, T. & Newman, P., Biophilic Cities Are Sustainable, Resilient Cities, *Sustainability*, **5(8)**, pp.3328-3345, 2013.

[3] Can biophilic urbanism deliver strong economic and social benefits? An economic and policy investigation into the increased use of natural elements in urban design; Sustainable Built Environment National Research Centre (SBEnrc),

http://www.sbenrc.com.au/wpcontent/uploads/2013/11/sbenrc_1.5biophilicurbanism-industryreport.pdf

[4] Newman, P. & Green, J., Paying for infrastructure means using 'land value capture', but does it also mean more tax? https://theconversation.com/paying-for-infrastructure-means-using-land-valuecapture-but-does-it-also-mean-more-tax-58731

[5] Newman, P., Sustainable urbanisation: four stages of infrastructure planning and progress. *Journal of Sustainable Urbanization, Planning and Progress*, **1(1)**, pp. 3–10, 2016.

[6] Ecosystem Evaluation, http://www.ecosystemvaluation.org/hedonic_pricing.htm

[7] Tomalty, R., Komorowski, B., *The Monetary Value of the Soft Benefits of Green Roofs. Final report*. Smart Cities Research Services: Montreal, 2010.

[8] Newman, P. & Matan, A., *Green Urbanism in Asia*. World Scientific Publishing: Hackensack NJ, 2013.

[9] Kellert, S., Biophilic urbanism: the potential to transform. *Smart and Sustainable Built Environment*, **5(1)**, pp. 4-8, 2016.

[10] Kellert, S., Heerwagen J. & Mador, M.L., *Biophilic Design. The Theory, Science, and Practice of Bringing Buildings to Life,* John Wiley & Sons: Hoboken NJ, 2008.

[11] Reeve, A., Desha, S., Hargroves, C., Newman, P. & Hargreaves, D. (2013). A Basis for Inquiry into Policy Consideration for Increasing the Application of Biophilic Urbanism. In S. Rauch, G. Morrison, S. Norra, N. Schleicher (ed.), Urban Environment. *Proc. of the 11th Urban Environment Symposium (UES*), *Karlsruhe, Germany, 16-19 September*, Springer International Publishing: Dordrecht, Switzerland, pp. 143-151, 2012.

[12] 14 Petterns of Biophilic Design. Improving Health & Well-being in the Built Environment; Terrapin Bright Green, 2012. http://www.terrapinbrightgreen.com/reports/14-patterns/

[13] Newman, P. & Jennings, I., *Cities as Sustainable Ecosystems. Principles and Practices,* Island Press: Washington DC, 2008.

[14] Clancy, J. & Ryan, C., The Role of Biophilic Design in Landscape Architecture for Health and Well-being. *Landscape Architecture Frontiers*, **3(1)**, pp. 54-61, 2015.

[15] Crompton, J., The Impact of Parks on Property Values: Empirical Evidence from the Past two Decades in the United States. *Managing Leisure,* **10(4)**, pp. 203-21, 2005.

[16] Wachter, S., The Determinants of Neighbourhood Transformations in Philadelphia-Identification and Analysis: The New Kensington Pilot Study, University of Pennsylvania, The Wharton School, 2004.

[17] Removing Freeways – Restoring Cities. Seoul, South Korea, Cheonggye Freeway; The Preservation Institute Web Site, Berkley CA, www.preservenet.com/freeways/FreewaysCheonggye.html

[18] Cheonggyecheon Stream Restoration Project – Seoul, South Korea Methodology for Landscape Performance Benefits; Landscape Architecture Foundation Web Site, Washington DC, http://landscapeperformance.org/case-study-briefs/cheonggyecheon-streamrestoration

[19] Green Infrastructure's contribution to economic growth: a review; Economics for the Environment Consultancy (eftec) and Centre for Regional Economic and Social Research (CRESR), Sheffield Hallam University Web Site, Sheffield, United Kingdom,

http://www4.shu.ac.uk/research/cresr/sites/shu.ac.uk/files/green-infrastructurescontribution-growth.pdf

[20] Green Walls Benefits; Green Roofs for Healthy Cities Web Site, http://www.greenroofs.org/index.php/about/green-wall-benefits

[21] Peck S.W., Callaghan C., Kuhn M.E., Bass B. Greenbacks from Green Roofs: Forging a New Industry in Canada. Status Report on Benefits, Barriers and Opportunities for Green Roof and Vertical Garden Technology Diffusion; Peck & Associates (P&A), Toronto ON, 1999,
https://www.nps.gov/tps/sustainability/greendocs/peck-sm.pdf

[22] Des Rosiers, F., Thériault, M., Kestens, Y., & Villeneuve P., Landscaping and house values: An empirical investigation. *Real Estate Research*, **23**, pp. 139–161, 2002.

[23] Ascher, K. & Uffer, S., The High Line Effect. *Proc. of the CTBUH Int. Conf. Conference On Global Interchanges: Resurgence of the Skyscraper*. New York, 2015.

[24] Levere, M., The Highline Park and Timing of Capitalization of Public Goods; Department of Economics, UC Sand Diego Web Site,

http://econweb.ucsd.edu/~mlevere/pdfs/highline_paper.pdf

[25] Triman, J., New urban rail parks seek to improve on High Line; Biophilic Cities Web Site,
http://biophiliccities.org/new-urban-rail-parks-seek-to-improve-on-high-line/

[26] Newman, P., Jones, E., Green, J. & Davies-Slate, S., Entrepreneur Rail Model. A discussion paper; Curtin University, Perth, Australia, 2016.

[27] Newman, P., Biophilic urbanism: a case study on Singapore. *Australian Planner*, **51(1)**, pp. 47-65, 2013.

Appendix D: Publication 2

Publication 2

Newman P. & **Cabanek A.** (2020) Bioregional Planning and Biophilic Urbanism. In D. Fanfani & A. Matarán Ruiz (Eds.), *Bioregional Planning and Design: Volume I*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-45870-6_7

Bioregional Planning and Biophilic Urbanism

Peter Newman and Agata Cabanek

1. Introduction

Bioregionalism has been part of cities from the beginning. Cities grew out of the opportunities they created but could only do this if their bioregional services – food, fuel, materials, water, waste absorption and ecological services – were adequate and well managed (Mumford 1961). When cities forgot this link or deliberately denied it, they collapsed (Diamond 2009). Prophetic voices like George Perkins Marsh said this in the nineteenth century (Marsh 1864), but the same can be seen in ancient times. The biblical prophet Isaiah railed about Babylon (a real city but also representing any city that developed such arrogance about its environmental context); Isaiah predicted the collapse of Babylon due to its overcutting of its surrounding forests (14:8) 2700 years ago.

In more recent times, bioregionalism has been rediscovered in the environmental movement, the territorialist movement (in Italy), the natural resource management or landcare movement (in Australia) and a multiple of expressions through urban and regional sustainability (Magnaghi 2005; Cork et al. 2007; McHarg 1969; Fanfani, 2009, 2013; Thayer 1997, 2009; Beatley 1999, 2012).

The link between bioregionalism and cities is not always made. Some bioregional perspectives, like those based around McHarg's environmental mapping, give a sense that a bioregion would be better off without the city. Such an approach, often described as romanticism, has a long history of reaction to industrial

P. Newman ( )

Distinguished Professor of Sustainability, Curtin University Sustainability Policy (CUSP) Institute, School of Design and the Built Environment, Curtin University, Perth, Australia e-mail: P.Newman@curtin.edu.au

A. Cabanek

Curtin University Sustainability Policy (CUSP) Institute, School of Design and the Built

Environment, Curtin University, Perth, Australia
e-mail: agata.cabanek@postgrad.curtin.edu.au

D. Fanfani, A. Matarán Ruiz (eds.), *Bioregional Planning and Design: Volume I*,
https://doi.org/10.1007/978-3-030-45870-6_7

modernism (Pepper 1996). But new movements are now appearing that are re-establishing the inherent integration of cities and their bioregion which are more positive about how the city can help recreate a better bioregion (Newman and Jennings 2008; Hes and Du Plessis 2015). One of these movements is biophilic urbanism. This chapter will show how bioregionalism and biophilic urbanism are related. It will attempt to show that cities can indeed begin their bioregional strategies from the biophilic design strategies. It will demonstrate this in some case studies, especially in Singapore.

2. Bioregionalism

A bioregion is defined by natural borders rather than by political borders, as in the Yellowstone to Yukon bioregion, which traverses state and national borders. Bioregional natural systems are critical for cities to function, but they are usually assumed to be separate from the built environment. These natural systems that surround the city include the water supply, local food and timber supplies; local materials for building; local waste-absorbing processes in air, water and soils; local biodiversity that provides the fundamental life forces of the regional ecosystem; and bioregional recreation spaces for the city. Such bioregional perspectives have been studied to minimise urban impacts for some time and are now part of a bioregional science (Thayer 1997, 2009; Fanfani 2009, 2013).

As cities consume or erode their natural environments, there has been growing concern that they must move from minimising their impact to rejuvenating their bioregional natural systems. If the natural systems are impacted too heavily, they can collapse, so the idea of regeneration is now being highlighted to not only minimise this but to repair the generations of damage that went before. The new ideas of resilient or regenerative design are now being applied (Lyle 1985, 1994; Thomson and Newman 2018). For example, many ideas for managing the increasing effects of climate change rely on green infrastructure which is multi-use infrastructure that uses natural systems to provide functions that traditionally were achieved by grey infrastructure systems, for example green space to absorb flooding, oyster beds to revive rivers and bioretention basins and swales (Matthews et al. 2016). Many of these projects go beyond resilience to actually regenerate the centuries of damage to their surrounding bioregion.

The more recent addition to bioregionalism is how cities can be even more regenerative through biophilic urbanism.

3. Biophilic Urbanism

Biophilic urbanism is based on the knowledge that humans have an innate connection with nature that should be expressed in their daily lives, especially in cities. Bringing nature onto and inside buildings has become the new focus and

requires a new science and a new governance. This has not been a strong feature of architectural principles and practice (even though there has been a long tradition of landscape architecture) yet potentially offers great rewards if it is implemented in the structure of the built environment.

Biophilia was a term first brought to life in 1964 by the psychoanalyst Erich Fromm in his exploration of the *Essence of Man*. He saw that humans' awareness of their "mortality" separates them from nature, causing deep anxiety and conflict (Fromm 1964). Humans try to overcome this anxiety by either a regressive path of narcissism, incestuous symbiosis, violence and necrophilia or a progressive path of altruism, freedom and biophilia. "Biophilia" was defined as a love of life and living processes.

The concept of the biophilic human being was then examined and popularised in 1984 by a sociobiologist, E.O. Wilson, in his book *Biophilia*. Wilson defined biophilia as "the innate tendency to focus on life and lifelike processes". He utilised the term "biophilia" to describe his deep feelings of connection to nature during a period of exploration and immersion in the natural world. Wilson's special insight was that this biophilic propensity developed as part of evolutionary survival so it encompasses certain characteristics that remain with humans even in modern cities and thus must be built into its everyday architecture (Wilson 1984; Kellert and Wilson 1993).

Today biophilic urbanism has become a major social movement within city policy and practice. The movement from ecology to the built environment can be seen in the collected work edited by Stephen Kellert and others, *Biophilic Design*: *The Theory, Science, and Practice of Bringing Buildings to Life* (Kellert et al. 2008), largely focused on the building level, to Timothy Beatley's book, *Biophilic Cities*: *Integrating Nature into Urban Design and Planning* (2011). There is now a Biophilic Cities Network with membership across the globe; the network enables cities to share information on how to mainstream biophilic urbanism into the policies and practices of cities.

The special niche of biophilic urbanism has been its focus on how to apply greenery into and onto the buildings that make up our cities, predominantly through green roofs and vertical greenery that have changed buildings from being concrete and steel designed to separate urban life from nature to living walls and roofs that are now seen as habitat sites with a new kind of design aesthetic (Kellert et al. 2008; Kellert 2008). As a result, a wide range of designs and methods for integrating nature into the built environment have emerged and continue to evolve with the potential of linking into bioregional regenerative outcomes.

3.1 Green Roofs

Green roofs are being developed across the world based on a range of new materials and new technologies as well as new science of what species will thrive in different areas (Dunnett and Kingsbury 2008; Wood et al. 2014). They are also being built for different reasons. North America is discovering that they are a very effective and popular option for managing stormwater and reducing the urban heat island effect. Basel, in Switzerland, has been installing green roofs for the past 16 years with a focus on increasing biodiversity. Where there may be a sole initial driver for the green roof installation, the multiple benefits are discovered which then

tends to lead to a ripple effect of further green roofs being installed in the surrounding area (Soderlund and Newman 2015).

Chicago first conducted a green roof trial on their City Hall, and its success led to incentives and regulations to encourage further green roofs in the City of Chicago. The driver for this was the need to cool the city and reduce the urban heat island effect. By 2010, Chicago had 359 green roofs totalling 51 hectares, and the Chicago City Hall green roof has become an icon for Chicago's sustainability movement.

Green roofs can be intensive or extensive like the California Academy of Sciences in San Francisco or Millennium Park in Chicago which is an extensive (10 hectare) green roof built over parking lots; this project has resulted in increasing tourism and further development bringing $3–5 billion economic benefit to the area (Soderlund 2016).

Green roofs can become part of a city's building policy with strong incentives such as extra density if provided or just the encouragement of a city policy. Germany began with incentives in 1983 followed by Basel, Switzerland, in 2000. Both countries currently have a high number of green roofs, and it is now an accepted form of practice. Washington initiated a green roof rebate program in 2005 and, as part of their Sustainable DC strategy, aims to have 20 million sq. ft. green roofs by 2020. Many global cities have initiated some form of incentives encouraging green roof construction in their cities. Austrian cities Vienna, Linz, Salzburg and Graz provide multiple grants and subsidies to support various green infrastructures being installed, including green roofs. Globally there is a growing tool kit of options for biophilic urbanism policy. This requires not just green roofs but green walls as well.

3.2 Green Walls

French botanist Patrick Blanc was the first to demonstrate extensive green walls; he created large, artistic and prominent green walls with plant species selected from waterfall rock-face plants. Blanc's walls are hydroponic panel systems which are quite thin, thus enabling them to be large and tall. Since these spectacular examples, green walls of all kinds have sprouted across the world (Blanc 2008).

Green walls are suitable for both indoor and outdoor locations. The resulting benefits will vary with the site, and, in some climates, indoor placement brings greater benefits. Toronto has discovered this with indoor biofilter green walls developed from NASA space technology research. These biofilter green walls significantly improve indoor air quality through a filtering system primarily involving the plant roots and soil microbes. Biofilter walls are also beginning to be recognised scientifically where a 2-year study of an installation in Sydney suggested impressive results of significant indoor particulate and carbon dioxide reductions (Burchett and Torpy 2011).

There is a growing body of evidence about such projects as the Toronto indoor biofilters, which have been a popular addition in developments, that they have multiple social, environmental and economic benefits.

3.3 Benefits of Biophilic Urbanism

Socio-psychological and environmental benefits are the most studied elements of biophilic urbanism (Newman et al. 2017). These are likely to combine and contribute to significant economic benefits such as better workplace productivity, improved health and healing, increased retail potential, decreased crime and violence, increased property values and employee attraction and increased liveability in dense areas. These are set out in Table 1 along with some estimates of economic benefit from each.

There are many obvious benefits of biophilic urbanism, but most of the literature and work by the biophilic urbanists are on how it can benefit cities as though they were not part of a bioregion. So how does biophilic urbanism help with bioregional agendas and how can bioregionalism help the biophilic urbanism agendas?

4. Linking Bioregionalism and Biophilic Urbanism

In order for biophilic urbanism to assist with a broader bioregional agenda, it will need to focus on how the natural features that are being introduced onto and into built structures can improve bioregional outcomes. Like all landscape architecture, bioregional-oriented biophilic urbanism needs to see how the choice of plants and their ecological structures can assist in a range of outcomes being sought by bioregionalism. It can also start as a bioregional policy which is translated into a local biophilic urbanism policy and extends the potential outcomes. There are several ways that biophilic urbanism can help with the bioregionalism agenda; the three examined here to illustrate the links are ecosystem services, biodiversity and sense of place.

Table 1 Economic benefits of biophilic urbanism

Area of benefit	Estimated economic and environmental benefit
Better workplace productivity	$2000 per employee per year from daylighting $2990 per employee over 4 months when desks angled to view nature
Improved health and healing	$93 million per year in reduced hospital cost of natural features provided in the US hospitals
Increased retail potential	Skylighting in a chain store would result in a 40% sale increase, ±7% 25% higher sales in vegetated street frontage
Decreased crime and violence	Public housing with greenery had 52% reduction in felonies Biophilic landscapes introduced across New York City would have $1.7 billion through crime reduction
Increased property values	Biophilic buildings attract higher rental prices, 3% per square foot or 7% in effective rents, selling at prices 16% higher
Employee attraction	Biophilics attract and retain high-quality workers
Increased liveability in dense areas	Green features increase saleability of densely built apartments blocks

Carbon sequestration	In Singapore, aboveground vegetation sequesters 7.8% of the total emitted daily carbon dioxide
Reduced urban heat island effect and reduced energy consumption	Due to shading provided by urban trees, in Los Angeles, annual residential air-conditioning (A/C) bills can be reduced directly by about US$100 million, additional savings of US$70 million in indirect cooling, US$360 million in smog-reduction benefits
Water management and quality	Up to 70% of stormwater retention capability depending of the local climate and other conditions
Air quality	Urban street canyons full of greenery can reduce particulate matter by up to 60% and nitrogen dioxide by up to 40%
Biodiversity conservation	A study of 115 wildly colonised green roofs in north of France found that 86% of species were native to the area

Source: Newman et al. (2017)

4.1 Ecosystem Services

The choice and type of biophilic services in a city can greatly assist bioregional watershed management, waste management and the provision of resources such as energy, materials, food and water. Cities covered in hard surfaces need to slow down stormwater flows, and there is much evidence of this now being mainstreamed, for example permeable and porous pavements infiltrate rain water which can be stored in underground tanks as in Vitoria-Gasteiz. Cities with substantial vegetation can clean the air and water; they can absorb grey water through bioswales and rain gardens to help grow biophilic landscaping, especially in areas where water is scarce at certain times of the year. Cities can provide particular types of food such as vegetables, herbs and spices because they are so labour-intensive, reducing food miles as many restaurants are now using to attract customers. Cities can provide water through their own urban catchments as well as drawing from their bioregional surrounds as in Singapore (outlined below). Cities can provide their own energy from local renewable sources thus reducing the impact on bioregions or working in partnership to share resources like biofuels as in Perth's White Gum Valley project (Newman et al. 2017).

The key, as to whether cities do this, will be whether cities plan for this or not. Modernist planning expectations certainly did not include such agendas, but new technologies for small-scale water, energy, waste and materials can combine with the expertise from biophilic scientists to enable such agendas to be mainstreamed (Newman 2005; Beatley 2011).

4.2 Biodiversity

With declining global biodiversity, increasing the availability of habitat in cities through increased urban vegetation is an obvious focus for progressive cities. The United Nations 2012 conference on biodiversity combined most of the world's nations in a pledge to increase commitment and spending on halting the rate of species loss; but it will be cities that mostly are able to do this. Green roofs and

green walls have multiple benefits, but if carefully integrated into urban landscaping and bioregional ecosystems, they can also help with biodiversity.

Cities in Switzerland, particularly Basel, have been studying the progression of biodiversity associated with their green roofs with encouraging results, resulting in mandatory green roofs on new flat-roofed buildings similar to Toronto. Some bird species are beginning to colonise Swiss green roofs. In a study of 115 “wild-colonised” green roofs in northern French cities, 86% of the colonies were found to be native plants. This suggests that, once established, biophilic architectural features could act as important sites for biodiversity colonisation from the surrounding bioregion (Brenneisan 2006; Baumann 2006; Madre et al. 2014).

The key to enabling a biodiversity link is to see how plant species and habitat structures can be designed with a bioregional perspective, not just a local aesthetic perspective. This will take scientific monitoring and studies to ensure it is working.

4.3 Sense of Place

A bioregional approach to urban design helps to create a sense of place. Beatley and Newman (2013) make a case that biophilic cities are overlapping in their desire to be sustainable and resilient through a range of place-oriented strategies that are trying to make the built environment more sensitive to its local, regional and planetary environment. Newman and Jennings (2008, p 144–155) developed five strategies for cities to enable them to foster a sense of place. One of those is “to connect the urban form to the wider bioregion”. To achieve that, local planning authorities must provide planning criteria and tools and fund necessary biophilic structures to connect the city to its bioregion. Cities located in a particular bioregion need to have the characteristics of their regional ecosystem at the heart of their biophilic systems.

In Europe, planning regional ecological networks to connect urban and rural natural systems has a long tradition. A flagship example of biophilic urbanism linking to regional ecosystems has been delivered in Vitoria-Gasteiz in Spain. The capital city of the Basque Country has had a policy for some time to join urban and rural natural systems creating a network that provides a number of eco-services as well enhancing humans’ well-being (Beatley 1999, 2012). The sense of place that has been generated permeates from the bioregion through to its parks, boulevards, and buildings. The green infrastructure creates channels connecting the greenbelt and its parks to the greenery in the city. The green network provides favourable conditions for enhancing urban and rural biodiversity recreating lost habitats. One of the important biophilic projects was naturalisation of a stream, which once was channelled in a concrete pipe. The stream, boarded by native riparian vegetation and traditionally reinforced embankment, runs along Gasteiz Hiribidea Avenue. Together with an impressive green envelope at the Palace of Europe, the stream creates a biodiversity hotspot in the city centre providing habitat to more than 70 butterfly species, many insects, and small animals (Beatley 2012) (Fig. 1).

5. Singapore: Biophilic City

Few cities have gone as far as Singapore with their biophilic urbanism. The island state has revegetated much of its previously cleared areas increasing canopy cover by 40% between 1986 and 2007. The goal of the city is to move from being a “garden city” to a “city in a garden” or even a “city in a forest”. Canopies have been built over most major roads and parks with different levels of habitat as well. Corridors of greenery have been built across the city called Park Connectors providing walking and cycling access only. Perhaps most impressive though has been the commitment to green roofs and green walls into hundreds of buildings based on a new science of how to apply it in Singapore’s climate developed by the government and freely provided. The enthusiasm of government, private sector and community groups for their biophilic city is evident in a number of films about Singapore (Newman et al. 2012).

Biophilic urbanism is now being mainstreamed into the town planning system in Singapore. New buildings in Singapore are now required to have a Green Floor Plate Ratio which requires them to replace the floor plate of the development with at least the same and sometimes twice as much greenery as the floor plate area (Newman 2014; Ong 2003). WOHA, the architects of Singapore’s award-winning Park Royal Hotel also known as the “jungle hotel”, took great advantage of Singapore’s green area ratio (GAR) to maximise green space and biodiversity, achieving a 5 to 1 ratio (Fig. 2).

Singapore’s global leadership in biophilic urbanism has been recognised (Newman 2014), so other cities are now copying them. For example, Washington D.C. recently created a green area ratio (GAR), modelled after Singapore’s, which requires developers to replace the green space they have built over into their

Fig. 1 Regenerated urban stream from stormwater pipe in Vitoria-Gasteiz, bringing bioregional biodiversity into the city. (Source Photo Agata Cabanek)

building's roof and facade. D.C.'s new stormwater runoff and GAR fees are expected to pay for many more biophilic projects (https://doee.dc.gov/GAR).

The goals of linking ecosystem service, biodiversity and sense of place are seen to overlap in all the new biophilic projects being built in Singapore such as the Gardens by the Bay which an educational area is showing the whole variety of biodiversity in its bioregion and creating multiple habitat sites to demonstrate them (Fig. 3).

Fig. 2 Singapore's Park Royal Hotel which achieved a green floor ratio of 5:1. (Source Photo

Peter Newman (Colour figure online)).

Singapore's KTP hospital incorporated greenery and biophilic design throughout the hospital in the hope that it would not only improve healing rates but that this initiative would encourage butterflies back. Both have happened. A goal of 100 butterfly species was set, and after 3 years, 102 species were sighted at the hospital (Newman and Matan 2012) (Fig. 4).

Three key conclusions about the value of biophilic urbanism and how it is relating to bioregionalism can be drawn from Singapore:

(a). *Singapore shows how the stigma can be removed from density as not being a feature of green cities.*

Singapore's biophilic urbanism has shown the world how a dense city can regenerate natural systems and create far more natural urban systems. It is doing this between buildings and all over buildings using their structures to create new urban ecosystems never considered possible before (Fig. 5) of a high-rise green facade. This is countering the problems of modernist buildings and their unattractive qualities to many people.

Singapore has demonstrated that density probably helps in two ways: (a) it enables concepts like Park Connectors and the Gardens by the Bay to be developed

Fig. 3 Singapore's Gardens by the Bay replaced a reclaimed area with a range of technologically creative habitats and educational facilities for demonstrating bioregional biodiversity. (Source Photo Agata Cabanek)

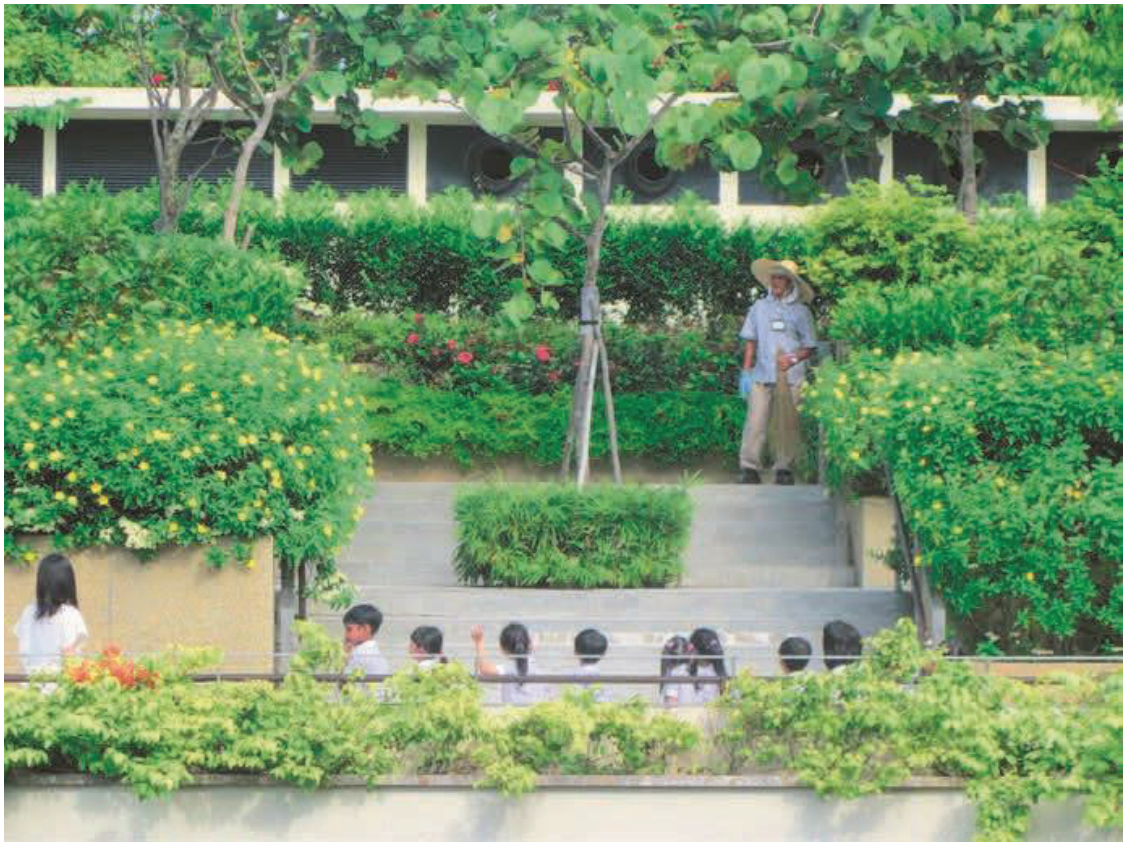


Fig. 4 KTP hospital in Singapore showing biophilic features that have made the hospital into a tourist attraction. (Source Photo Peter Newman)

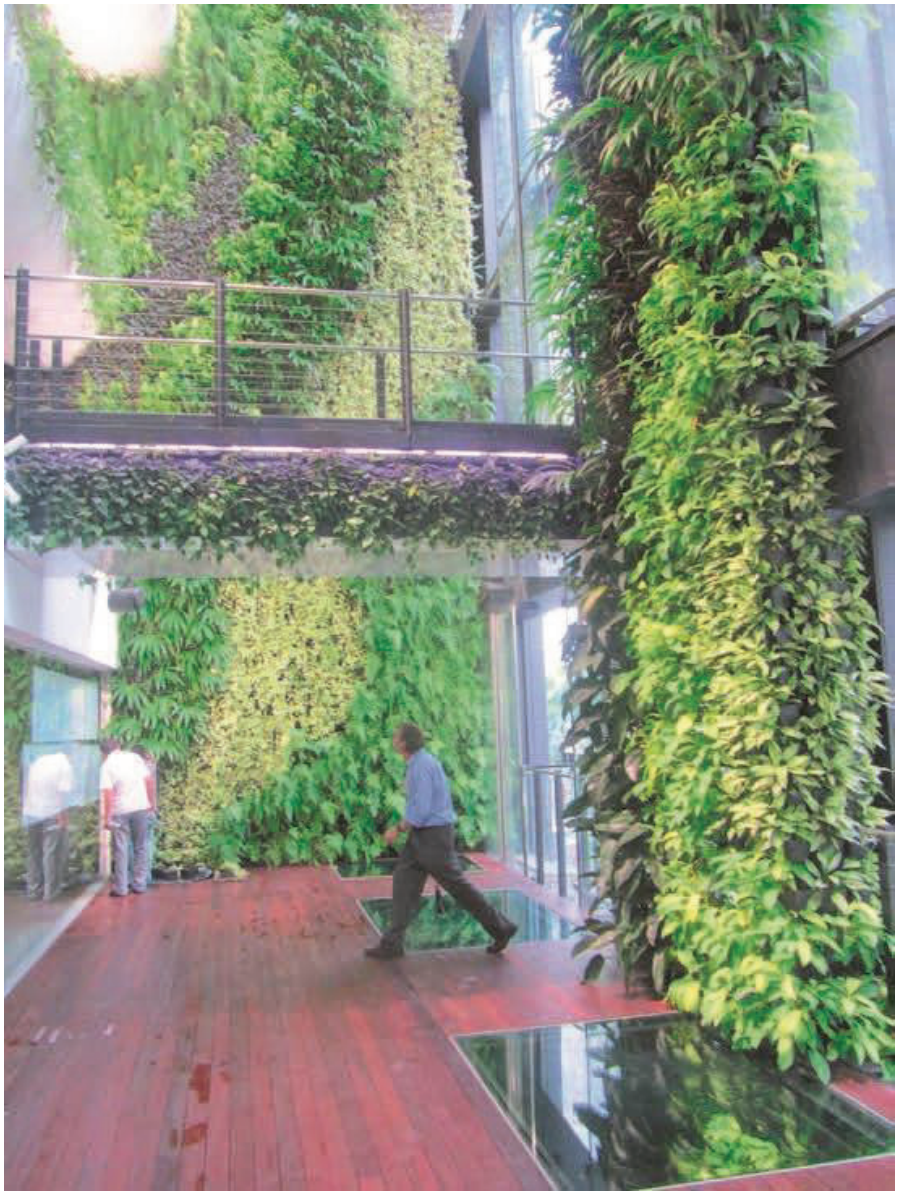


Fig. 5 High-rise green façade in Singapore high-rise office building. *Source* Photo Peter Newman

(Color figure online)

as they need intense land uses where distances are short; and (b) it enables the height of buildings to be used to help create a third dimension in an urban ecosystem. This means that a structure for biological activity can be created around buildings similar to the structure of tall forest. Thus the positive element of biophilic urbanism is that dense cities with high-rise buildings can perhaps provide more opportunities to build biophilic urban ecosystems than low-density suburbia, due to their extra habitat opportunities from high walls and flat roofs. This is a big issue as the world is trying to find ways of preventing car-dependent urban sprawl with all its oil, climate, health and economic implications, and most cities point to a powerful need for increased densities (Newman 2006). However, the need for natural systems to be part of this policy has always been a question that threatens to undermine the value in more compact cities. Perhaps biophilic urbanism is a way to

facilitate green and attractive cities that are also far more efficient in resources? To take away the stigma of density would be a significant bioregional planning contribution from biophilic urbanism now clearly demonstrated in Singapore.

(b). *Singapore has shown how a city can make a contribution to local and bioregional biodiversity.*

Singapore's NParks started measuring biodiversity when they began their biophilic experiments. They have pioneered the Singapore Biodiversity Index which has been adopted by many cities around the world. These data are now showing that new and rare species are being found in Singapore long after they were thought to have disappeared from the urban area. The many local examples set out in a series of beautiful publications from the city all show rapid increases in birdlife and other biodiversity as soon as habitat is provided, whether it is using local species or not. Indeed many of the tree species used to provide the structure of their urban ecosystems are not native, like the rain trees used to structure canopy cover over roads and parks (because their root systems fit into urban areas). KTP Hospital measures biodiversity in birds, fish and butterflies, and all are going up as their biophilic features mature.

Biophilic urbanism like that demonstrated in Singapore is unlikely to recreate the pre-urban ecosystem nor is that ever claimed. But it can do far more to recreate the structure of the ecosystem in any area as it can use the diversity of a city's built forms and microclimates to create urban ecosystems far more biodiverse and complete in their structures than in the unidimensional urban parks and gardens we are used to. In this, it is more like the regenerative design paradigm mentioned earlier.

(c). *Singapore has shown how new kinds of bioregionally oriented urban ecosystems can be imagined developing if biophilic urbanism is taken seriously.*

As the biophilic urbanism in Singapore spreads and matures into a more complete coverage of the urban environment, it can be expected that not only will local biodiversity rise but a better understanding of how urban ecosystems can help bioregions regenerate. It is not the same as the pre-city rain forest, but it will have many features of a rain forest except it will also contain a city full of people.

6. The Next Stage in Singapore's Biophilic Urbanism

There are two new projects that take Singapore's biophilic urbanism into new territory and can help show bioregional outcomes. The projects are new urban areas being built on sites that are highly degraded – one is a degraded industrial area and the other is a section of coastline that has been reclaimed using earth fill and recycled rubbish. Their biophilic design strategies as part of their strategic planning are providing a new opportunity for bioregionalism.

The two new projects are redeveloping areas for extra housing and in the process are regenerating the natural features of the area using bioregional principles and then bringing these back into the biophilic urbanism being used in and on buildings. One is taking a former river delta area that had been drained and channelised into

concrete drains and will recreate some of the former river mouth ecosystem. It will then take some of the features of this ecosystem back into how the landscape is created around and on the buildings for the new housing area. It is thus joining the natural features of the area into the built form and regenerating the former ecosystem. The other project is on the coast and will be using coastal ecosystem features to regenerate the area from a reclaimed concrete wall into a thriving natural area; it will then bring these features into the green roofs and green walls of the new housing area (Ming et al. 2010; Yabuka 2018).

Biophilic urbanism has emerged in the USA but is not just an American phenomenon. Singapore has shown, perhaps more than any other city, how a dense Asian city can bring nature into the city in new and exciting ways. Perhaps the most important outcome of Singapore's biophilic urbanism is that it has proved not only that density does not preclude a city from bringing nature more intensely into the daily life of a city but in fact density may assist this.

The rapidity with which Singapore has made this transition from being a modernist city, where nature was kept at a distance from urban development to embracing it at every point of the city's development and buildings, suggests that any city wanting to make a contribution to biodiversity and to creating a healthier and more complete urban ecosystem can now do it. The technology of green walls and green roofs is now available and needs to be trialled in many different urban environments. The results can be a city where a new kind of urban nature develops that fulfils the functions of the original ecosystem replaced by the city and which contributes to bioregional outcomes.

7. Conclusions

Bioregional planning and biophilic urbanism are natural allies in many aspects of environmental planning. There is a need for bioregionalism to bring its insights and science right into the city and down to the detailed landscaping in and on buildings, and there is a need for biophilic urbanism to extend their science and insights out into the corridors and surroundings of the bioregion that supports every city. Such linkages will need to be demonstrated more and more such as the two new redevelopment case studies in Singapore. It is possible that a new kind of biophilic urbanism will be created that is more related to the local ecology and bioregional restoration, gaining its design motivation not from a collection of plants from around the world but from the restored local ecology. At the same time, the case studies could be rejuvenating bioregionalism because it grows out of the city and its development rather than being just what happens outside and around the city. Such potential integration of bioregionalism and biophilic urbanism is needed in all cities.

References

Beatley, T. (1999). *Green urbanism: Learning from cities in Europe*. Washington, DC: Island Press.

Beatley, T. (2011). *Biophilic cities: Integrating nature into Urban Design and planning*. Washington, DC: Island Press.

Beatley, T. (Ed.). (2012). *Green cities of Europe: Global lesson on green urbanism*. Washington, DC: Island Press.

Beatley, T., & Newman, P. (2013). Biophilic cities are sustainable resilient cities. *Sustainability, 5*, 3328–3345. https://doi.org/10.3390/su5083328.

Blanc, P. (2008). The vertical garden: From nature to the city. New York: W.W. Norton & Company,

Brenneisan, S. (2006). Space for urban wildlife: Designing green roofs as habitats in Switzerland. *Urban Habitat, 4*, 27–36.

Baumann, N. (2006). Ground-nesting birds on green roofs in Switzerland: Preliminary observations. *Urban Habitat, 4*, 37–50.

Burchett, M. D., & Torpy, F. (2011). *How humble houseplants can improve your health, lecture recording, UTS Science in Focus, UTS, Sydney*. Available: https://www.uts.edu.au/about/ faculty-science/partners-and-community/uts-science-focus/medical-and-biomedical-sciences/ how-humble-houseplants-can-improve-your-health. Accessed 18 May 2020.

Cork, S., Stoneham, G., & Lowe, K. (2007). *Ecosystem services and Australian natural resource management (NRM) futures*. Canberra: NRMSC, Commonwealth of Australia.

Diamond, J. (2009). *Collapse: How societies choose to fail or succeed*. New York: Viking Books.

Dunnett, N., & Kingsbury, N. (2008). *Planting green roofs and living walls* (2nd ed.). London: Timber Press.

Fanfani, D. (2009). Multifunctional planning of the Periurban territory and limiting land consumption. The strategic scenario for the “Polycentric City of Central-Western Tuscany”. In B. Badiani & M. Tira (Eds.), *Urban containment: The Italian approach in the European perspective* (pp. 55–70). Sant’Arcangelo di Romagna: Maggioli. isbn: 9788838743634

Fanfani, D. (2013). Local development and Agri urban domain: Agricultural Park as promotion of an ‘Active Ruralship’. *Planum: The Journal of Urbanism, 27*(2), 38–47.

Fromm, E. (1964). *The heart of man*. New York: Harper and Row.

Hes, D., & Du Plessis, C. (2015). *Designing for Hope: Pathways to regenerative sustainability*. Abingdon: Routledge.

Kellert, S. R., & Wilson, E. O. (1993). *The biophilia hypothesis*. Washington, DC: Island Press.

Kellert, S. R., Heerwagen, J., & Mador, M. (2008). *Biophilic design: The theory, science, and practice of bringing buildings to life*. Hoboken, NJ: Wiley.

Kellert, S. R. (2008). Dimensions, elements, and attributes of biophilic design. In S. R. Kellert, J. Heerwagen, & M. L. Mador (Eds.), *Biophilic design* (pp. 3–19). New Jersey: Wiley.

Lyle, J. T. (1985). *Design for human ecosystems: Landscape, land use, and natural resources*. New York: Van Nostrand Reinhold.

Lyle, J. T. (1994). *Regenerative Design for Sustainable Development*. New York: Wiley.

Magnaghi, A. (2005). *The Urban Village: A charter for democracy and local self-sustainable development*. London/New York: Zed Books.

Madre, F., Vergnes, A., Machon, N., et al. (2014). Green roofs as habitats for wild plant species in urban landscapes: First insights from a large-scale sampling. *Landscape Urban Plan, 122*, 100–107.

Marsh, G. P. (1864). *Man and nature, or physical geography as modified by human action*. London: Samson Low Son and Marston.

Matthews, T., Ambrey, C., Baker, D., & Byrne, J. (2016). How green infrastructure can easily be added to the planning toolkit. *The Conversation,* April 26. Retrieved from: https:// theconversation.com/heres-how-green-infrastructure-can-easily-be-added-to-the-urbanplanning-toolkit-57277.

McHarg, I. L. (1969). *Design with nature*. New York: Natural History Press.

Ming, L. J., Suan, T. P., & Toh, W. (2010). HDB's next generation of eco-districts at Punggol and eco-modernisation of existing towns. *The IES Journal Part A: Civil & Structural Engineering, 3*(3), 203–209. https://doi.org/10.1080/19373260.2010.491259.

Mumford, L. (1961). *The city in history*. London: Penguin Press.

Newman, P. (2005). The city and the bush-partnerships to reverse the population decline in Australia's Wheatbelt. *Australian Journal of Agricultural Research, 56*, 527–535.

Newman, P. (2006). The environmental impact of cities. *Environment and Urbanization, 18*(2), 275–295.

Newman, P. (2014). Biophilic urbanism: A case study of Singapore. *Australian Planner, 1*, 47–65.

Newman, P., Beatley, T. & Blagg, L. (2012). *Singapore 'biophilic city'* [Online]. You Tube.

Available: https://www.youtube.com/watch?v=XMWOu9xIM_k [Accessed 23/04/2014].

Newman, P., & Jennings, I. (2008). *Cities as sustainable ecosystems*. Washington, DC: Island Press.

Newman, P., & Matan, A. (2012). *Green Urbanism in Asia*. Singapore: World Scientific Publishing Company.

Newman, P., Beatley. T., & Boyer, H. (2017). *Resilient Cities. Overcoming Fossil Fuel Dependence* (2nd Edn.). Washington, DC: Island Press.

Ong, B. L. (2003). Green plot ratio: an ecological measure for architecture and urban planning. *Landscape and Urban Planning, 63*(4), 197–211.

Pepper, D. (1996). *Modern environmentalism: An introduction*. Abingdon: Routledge.

Soderlund, J., & Newman, P. (2015). Biophilic architecture: A review of the rationale and outcomes. *AIMS Environmental Science, 2*(4), 950–969. https://doi.org/10.3934/environsci.2015.4.950.

Soderlund, J. (2016). *Biophilic urbanism an emerging social movement,* PhD Curtin University, Perth, Australia.

Thayer, R. L. (1997). *Gray world, green heart: Technology, nature, and the sustainable landscape*. New York: Wiley.

Thayer, R. L. (2009). *LifePlace: Bioregional thought and practice*. California, CA: University of California Press.

Thomson, G., & Newman, P. (2018). Urban fabrics and urban metabolism - from sustainable to regenerative cities. *Resources, Conservation and Recycling, 132*, 218–229.

Wilson, E. O. (1984). *Biophilia*. Cambridge, MA: Harvard University Press.

Wood, A., Bahrami, P., & Safarik, D. (2014). *Green walls in high-rise buildings: An output of the CTBUH sustainability working group. Council of Tall Buildings and Urban Habitat*. Mulgrave, VIC: The Images Publishing Group Pry Ltd..

Yabuka, N. (2018). HDB begins applying Biophilic design framework to new towns, *Indesignlive.sg*, 10 August. Retrieved from: https://www.indesignlive.sg/insight/ hdb-biophilic-design-framework-new-town

Appendix E: Publication 3

Publication 3

Cabanek, A., Zingoni de Baro, M.E. & Newman, P. (2020). Biophilic streets: a design framework for creating multiple urban benefits. *Sustainable Earth*, 3(7), https://doi.org/10.1186/s42055-020-00027-0

Cabanek et al. Sustainable Earth (2020) 3:7
https://doi.org/10.1186/s42055-020-00027-0

Sustainable Earth

RESEARCH Open Access

Biophilic streets: a design framework for creating multiple urban benefits

Agata Cabanek*, Maria Elena Zingoni de Baro and Peter Newman

Abstract

Biophilic urbanism is bringing new perspectives to how natural systems need to be integrated into the fabric of cities. This paper shows how biophilic streets can be the front door to biophilic urbanism by integrating nature into a new street design, benefiting a range of economic, environmental and social functions. A theoretical integrated Biophilic Streets Design Framework, is outlined and evaluated through the analysis of four street revitalisation projects from Vitoria-Gasteiz, Berkeley, Portland and Melbourne. Its practical applications and multiple urban benefits will be of value to street designers globally. The Biophilic Streets Design Framework demonstrated that the four case studies meet the main design categories, which is favourable since multiple additional benefits are likely to be obtained. Future research is needed to monitor and quantify the performance of biophilic streets design to address the increasing effects of climate change, environmental degradation and biodiversity loss in a cost-effective way.

Introduction

Streets have been the focus of public life in cities since they were first built [1, 2]; they provide the space and accessibility for close communal activity. The rediscovery of the social and economic value of streets since the work of Jane Jacobs [3], groups like Project for Public Spaces, and the detailed designs of Jan Gehl [4, 5], have enabled them to be seen as much more than spaces for mobility. This research seeks to integrate biophilic element into the design of new streets and the renewal of traditional ones to enhance the environmental component in the mix of benefits associated with streets.

Biophilic urbanism has emerged as a way to bring nature more purposefully into cities, not just between buildings and infrastructure, but into and onto them in ways that increase the connectivity between people and nature and derive benefits from natural services and functions [6–8]. Although the application of biophilic urbanism to streets has been present in the literature for some years and has informed the work of biophilic designers, it has not been formally developed into a design framework demonstrating how it can be delivered and what its multiple benefits are. This paper seeks to address the need for a theoretically and practice informed design framework to enable more effective delivery of biophilic urbanism.

Biophilia and related emerging concepts

The emerging concepts of biophilia, biophilic design and biophilic urbanism are primarily concerned with human inclinations to affiliate with nature in urbanised environments such as cities, as suggested by Wilson [9], Kellert Heerwagen and Mador [6] and Beatley [7].

The term biophilia was first used by the German psychoanalyst Erich Fromm in 1973 and defined as 'love of life'. The American biologist E.O. Wilson advanced studies on this subject, expanding and popularising the concept of biophilia as the innate affinity of human beings with all forms of life and their inherent tendency to focus on lifelike processes in his seminal book, Biophilia (1984) [9]. Further studies demonstrated that this human inclination to affiliate with nature appears to be critical for human physical and mental health in the modern urbanised world due to humanity's origins in nature [8, 10–12]. Salingaros [12] studied this relationship in depth, also studying how humans developed their sensory space. He suggested that there are particular and very specific geometrical properties found in the

* Correspondence: agata.cabanek@postgrad.curtin.edu.au
Curtin University Sustainability Policy Institute, Perth, Australia

structure of nature and in the built environment which have a positive and uplifting influence on human physical and mental conditions. These properties applied to design can therefore enhance the quality of life in urban centres. This process, called the 'biophilic effect' by Salingaros, relies on an intimate informational connection between humans and nature, and supports the need to introduce natural systems into the design of built environments [12]. Kellert [6] defined and described six biophilic design elements and seventy attributes that were later summarised for practical application in architectural and urban design. Kellert and Calabrese considered biophilic design as a means for sustainable development because it could promote care, stewardship, and attachment to place [10].

Biophilic design attempts to achieve the benefits of contact between people and nature within the modern built environment [6, 10, 11] by integrating nature, internally and externally, into buildings, built infrastructure and across the urban space [7]. By adopting the strategies of this design principle, creating habitats for people, as biological organisms, that restore or enhance their physical and mental health, fitness and well-being becomes viable [10]. In addition to anthropocentric goals and benefits, biophilic design is a recognised solution to a spectrum of environmental challenges including urban heat island effect, particulate matter filtration and carbon dioxide sequestration, rehabilitation and restoration of lost habitats and increase of urban biodiversity. It promotes ecologically interrelated design solutions at multiple scales and enables regeneration of natural systems in the urban environment [8, 13–15].

Beatley (2011) extended the concept of biophilic design to the urban scale, imagining and encouraging biophilic cities. Biophilic urbanism was presented as an emerging planning and urban design approach that aimed to systematically integrate nature into the urban fabric, igniting the potential to transform barren urban spaces into places that are restorative and conducive to life [7, 13]. Biophilic urbanism focuses on ecological systems and human activities delivered by biophilic interventions and projects. The main goal of biophilic urbanism is to improve the connection between urban dwellers and urban nature and nourish the experience of nature on a daily basis as an integral part of urban living [6–8]. In this sense, biophilic design and urbanism deliberately facilitate opportunities for urban residents to experience nature daily [7, 10].

The global shift towards biophilic design continues to grow. Although the terminology used varies, there are initiatives in many countries that focus on the role of nature as an essential element of everyday urban life [8]. Recent studies have shown that experiencing nature on a daily basis supports people's mental and physical health [7, 16–19]. Table 1 below outlines the multiple benefits of biophilic design to the environmental, socio-psychological and economic aspects of urban life.

Biophilic theorists Stephen Kellert and Elisabeth Calabrese [10] have formulated a range of biophilic experiences and attributes (Table 2) to facilitate the application of biophilic design theory to practice that delivers buildings and urban spaces that facilitate direct and indirect experiences of nature for urban dwellers in their daily lives. These experiences and attributes serve as principles to inform the balanced design of biophilic urban spaces. Some of these experiences are difficult to encounter in conventional streets; however, they can be incorporated into the renewal of conventional streets and the design of new ones by biophilia-literate designers.

To ensure ongoing exposure to and interaction with nature, both bond and commitment to place are needed. In order to achieve these, a design must be founded on a sound understanding of urban nature and its ecosystems as well as a sense of place. This is likely to lead to more frequent interactions between people and nature, thereby nurturing the bond between them and increasing the likelihood that residents will protect and save urban green spaces [20]. Some scholars argue that a relationship to place is needed to develop intimacy and responsibility for nature and the living world [21, 22]. Streets are an important part of any human settlement and, hence, this approach will be used to create a Biophilic Streets Design Framework presented in this paper.

A brief history of streets

Urban designers, planners and civil engineers have conceived and developed regulatory frameworks for streets to enable efficiency, security and, most of all, the rapid conveyancing of traffic, both public and private. However, the modernist tendency in the twentieth century, which saw the rise of automobile dependence, created rigid regulations that focused on efficiency and traffic control and directly contributed to the detachment of nature from urban ecologies, bioregions and climate dynamics [23]. By creating barriers in the form of dense networks of freeways and highways, the remaining urban natural areas became fragmented and isolated, along with the social neighbourhoods that they physically divided, thus disrupting their social integrity. Such impacts were built into the design frameworks created by traffic engineers.

Jane Jacobs challenged these approaches that prioritised private mobility over all other street functions and pointed to the diverse social networks characteristic of busy urban streets, which constitute the fabric of a city [3, 24]. Those social networks are created when the structure and amenities of a street provide space for interaction and promote walkability. The abundance of social networks provide opportunity for local businesses

Table 1 Environmental, socio-psychological and economic benefits from biophilic design based on Newman, Beatley and Boyer, 2017

Area of benefit	Estimated economic and environmental benefit
Better workplace productivity	$2000 per employee per year from daylighting; $2990 per employee over 4 months when desks angled to view nature.
Improved health and healing	$93 million per year in reduced hospital cost if natural features provided in the U.S. hospitals.
Increased retail potential	Skylighting in a chain store would result in a 40% sales increase, ±7%. 25% higher sales in vegetated street frontage.
Decreased crime and violence	Public housing with greenery had 52% reduction in felonies. Biophilic landscapes introduced across New York City would save $1.7 billion through crime reduction.
Increased property values	Biophilic buildings attract higher rental prices, 3% per square foot or 7% in effective rents, selling at prices 16% higher.
Employee attraction	Biophilics attract and retain high-quality workers.
Increased liveability in dense areas	Green features increase salability of densely built apartment blocks.
Carbon sequestration	In Singapore aboveground vegetation sequesters 7.8% of the total emitted daily carbon dioxide (Velasco et al., 2016).
Reduced urban heat island effect and reduced energy consumption	Due to shading provided by urban trees, in Los Angeles annual residential air-conditioning (A/C) bills can be reduced directly by about US$100 million, additional savings of US$70 million in indirect cooling, US$360 million in smog-reduction benefits (Rosenfeld et al., 1998).
Water management and quality	Up to 70% of stormwater retention capability, depending of the local climate and other conditions.
Air quality	Urban street canyons full of greenery can reduce particulate matter by up to 60% and nitrogen dioxide by up to 40%.
Biodiversity conservation	A study of 115 wildly colonized green roofs in north of France found that 86% of species were native to the area.

to thrive; hence, Jacobs was able to construct a theoretical approach to show why streets were essential to a city's economy [25, 26]. This has since developed into a strong plea for dense urbanism and street fabric to be seen as essential components of how cities create wealth and opportunity [27–30].

Urban designers, such as Jan Gehl, criticised modernist planning ideologies and how they dismissed the value of historic streets by allowing cars to invade every available space in cities [4, 31]. Through a series of reports on cities around the world, Gehl created a new framework for how streets should be designed to facilitate close interactions between people that enable multiple economic and social benefits and reduce the environmental impact of cars [31, 32]. Gehl's framework for urban planners, landscape architects and architects reinforces walkability, active street frontages and street furniture as integral parts of city policy [31], to ensure streets are welcoming spaces in the pattern of daily activities. Table 3 below shows Gehl's 12 quality criteria as a framework for this approach to street design, with an additional column that shows how biophilic design interventions can enrich the pedestrian landscape and experience.

Cities are changing from sprawl and car dependency to transit and more compact urban forms, and so are their streets. The focus of urban streets is changing from ensuring traffic movement efficiency to a more people-centred design that puts pedestrians first, then cyclists and transit, and lastly private motorised vehicles [33, 34]. Building on Gehl's work and collaborations among experts from global cities, the National Association of City Transportation Officers (NACTO) created the *Global Street Design Guide* [35], which is intended to be a baseline for urban street design. The Guide aims to

Table 2 Experiences and attributes of biophilic design. Source: Kellert and Calabrese (2015)

Direct experience of nature	Indirect experience of nature	Experience of space and place
• Light • Air • Water • Plants • Animals • Weather • Natural Landscapes and Ecosystems • Fire	• Images of Nature • Natural Colours • Stimulating Natural Light and Air • Naturalistic Shapes and Forms • Evoking Nature • Information Richness • Age, Change, and the Patina of Time • Natural Geometries • Biomimicry	• Prospect and Refuge • Organized Complexity • Integration of Parts to Wholes • Transitional Spaces • Mobility and Wayfinding • Cultural and Ecological Attachment to Place

Table 3 Gehl's 12 quality criteria concerning the pedestrian landscape along with added biophilic design interventions

12 quality criteria concerning the pedestrian landscape (Gehl 2010,*p.* 239)				Biophilic design interventions
Protection	Protection against traffic and accidents – feeling safe Protection for Pedestrians and cyclists. Eliminating fear of traffic.	Protection against Crime & violence - feeling secure Lively public realm. Eyes on the street. Overlapping functions day and night. Good lighting.	Protection against Unpleasant sensory Experiences Wind. Rain/snow. Cold/heat. Pollution. Dust, noise, glare.	Vegetated hedges as protection from traffic. Tree canopy to mitigate weather conditions and reduce noise Plant palette designed to capture and retain airborne particulate matter Dynamic & diffuse lighting provided by tree and shrub planting, and water features; Mobile structures such as 'CityTree' and Mobile Forest, Pop-up parklets
Comfort	Opportunities to walk Room for walking. No obstacles. Good surfaces. Accessibility for everyone. Interesting facades.	Opprtunities to stand/stay Edge effect/attractive zones for standing/ staying. Support for standing.	Opportunities to sit Zones for sitting. Utilising advantages: view, sun, people. Good places to sit. Benches for resting.	Tree canopies Vegetated walk paths. Vertical gardens (creepers or green walls). Natural materials. Naturalistic shapes and forms (facades and pavements). Urban furniture integrated with plant beds, vertical gardens, water features. Creating interesting views with greeneries. Using vegetated hedges to create noise buffers/ intimate spaces/exercise and play spaces. Biophilic structures such as parklets, 'CityTree', Green bus stop shelters
	Opportunities to see Reasonable viewing distances. Unhindered sightlines. Interesting views. Lighting (when dark).	Opportunities to talk and listen Low noise level. Street furniture that provides 'talkscapes'.	Opportunities for play and exercise Invitations for creativity, physical activity, exercise and play. By day and night. In summer and winter.	
Delight	Scale Building and spaces designed to human scale.	Opportunities to enjoy the positive aspects of climate Sun/shade Heat/coolness Breeze	Positive sensory experiences Good design and detailing. Good materials. Fine views. Trees, plants, water.	Well-designed public green spaces to fit different age groups needs and expectations. Plant selection according to climate, soil, seasons to maximise sensory and aesthetic experiences. Use greeneries to (re) create human scale. Public art Mobile and temporary structures such as parklets, pop-up gardens, 'CityTree', Mobile Forest, Green bus shelters

better balance the needs of street users (with more emphasis on the needs of pedestrians) and supports the creation of quality spaces based on the consideration of people and place.

Finally, the concept of biophilic design contributes to the creation of urban streets with attractive, healthy, liveable and restorative environments and nature experiences at the door step for both dwellers and other street users within gradually densifying urban precincts through urban infill.

Developing a framework for biophilic streets design

An urban street can be compared to an evolving organism adapting and responding to its environment. Although cities contain a broad range of street typologies, depending on the context, they generally provide space for transportation, commuting, physical activities and social and economic life at different scales [36]. Traffic engineers and urban designers often fail to plan streets that deliver positive social or health-related outcomes. Reconceiving urban streets as places, rather than just movement spaces, would facilitate the provision of these positive outcomes. Furthermore, as the time people spend in streets compared to the time they spend in parks is eight to ten times more [37], the design of streets—to support health and well-being— should be considered before parks [36, 38].

Streets provide diverse experiences to their users, including the experience of nature. Identifying the most appropriate design strategies to apply to any given street would need to take into account a range of circumstances and requirements particular to that location. This may include the history of the street, the existing social, environmental, architectural and structural conditions, existing infrastructure, policies and regulations, project size, zoning and land use and its potential future as a place.

Based on the experiences of biophilic places (Table 2) and their many benefits, a list of the characteristics of a biophilic street were compiled as an analytical framework of six categories. These categories consider design functions, design objectives, design elements and the characteristics of a biophilic street. The six categories—traffic planning, energy management, stormwater management, biodiversity management, street furniture and activities and education—are derived from the intended purposes for which streets are designed, and chosen

because of their potential to be improved by the addition of biophilic elements. Elements that have been successfully designed, developed and applied in real-life projects form the base for a biophilic street. The proposed Framework is set out in Table 4 below, followed by an explanation of each category. It is then applied to four examples of a street revitalisation project to illustrate its usefulness.

Mobility planning

A street often serves as a front yard for residents; it must, therefore, provide a safe place to move around, whether by car, bicycle, transit or on foot. However, used only for transportation, a street loses its relevant social and economic functions, such as providing a safe space for interaction, as identified by Jacobs [3, 26] and Gehl [5]. In the wake of the urban renewal movement, many cities are restoring or redesigning their main streets and boulevards to serve as linear parks and other types of hospitable public places promoting social interaction and walking. As a result, the most successful transformations add value to adjacent properties and local businesses [39]. The Biophilic Streets Framework takes these fundamental characteristics of streets and seeks to show that there are biophilic design principles and strategies that could help streets perform these functions more effectively.

To achieve safety standards on biophilic streets, traffic calming schemes should apply, including techniques designed to lessen the impact of traffic. Trees and bushes are well known to do this by psychologically giving drivers a sense of needing to go slower [40]. The location of measures and devices (including types of vegetation) determines the effectiveness of traffic calming

Table 4 Framework for biophilic streets design

Framework functions and objectives		Biophilic design elements		
Design functions	Selected design objectives	Building façades	Road reserves	Pocket parks
Traffic planning	Creating space for biophilic designs by redesigning traffic lanes, traffic calming schemes, reducing lanes, prioritizing pedestrians, transit and bicycle lanes and providing pocket parks.	Integrating vertical greenery into and onto buildings, such as green walls, green balconies, planter boxes; green roofs.	Integrating native gardens, edible gardens, nature playgrounds and other biophilic features on verges, median strips, roundabout, 'ramblas', green bridges and flyovers, buffers between roads and cycling and/or pedestrian paths.	Integrating native gardens, edible gardens, nature playgrounds, water features, habitats for birds, insects and small animals, street furniture and amenities in median strips, 'ramblas', roundabouts, vacant lots, plazas, spaces between buildings.
Energy management	Cooling streets for walking, reducing urban heat island effect and saving energy through insulating buildings.	Green walls, roofs, and balconies to provide thermal insulation; cooling (evapotranspiration); air purification; relaxation. Combination of green roofs and solar panels.	Tree canopies that shade pedestrians as well as shading buildings.	Pocket parks can be built around all three energy management ideas.
Stormwater management	Water retention, purification, and reuse.	Green walls, green roofs, green balconies that filter rain.	Street trees, tree pits, linear gardens, bioswales, rain gardens, daylighted streams.	Rainwater tanks, pervious pavements.
Biodiversity management	Biodiversity enhancement, restoration, creation of various habitat sizes and types that enable regeneration of urban ecosystems.	Green walls, green roofs, green balconies.	Street trees, tree pits, linear gardens, bioswales, rain gardens, daylighting streams.	Plant beds, potted shrubs and trees, green walls, water features.
Street furniture	Incorporating biophilics into every small function in the street, including seats, signs, bus shelters, street art.	Street art combined with filtration systems to conduct runoff from green roofs.	Parklets Green roofs on top of bus and transit shelters. Street art combined with filtration systems. 'City trees' installation to facilitate air purification. Vertical pallet edible gardens.	Urban furniture to support natural systems. Green roofs on top of bus and transit shelters. Street art combined with filtration systems. 'City trees' installation to facilitate air purification. Vertical pallet edible gardens.
Activity and education	Enabling both activity that uses street functions and understanding of how nature fits into the city as well as the social and cultural value of the street.	Tourist and visitor information in streets explaining biophilic facades.	Integrated street furniture with green features explained. Educational features – information plates, educational stations; activity points (smart play equipment, art installations, water features).	Integrated street furniture with green features explained. Educational features – information plates, educational stations; activity points (smart play equipment, art installations, water features).

schemes, and those again depend on the type of streets they are introduced on: a residential road, a road with traffic functions or a transit road having a combination of speeds that enable rapid mobility (between stations) and slow mobility (within station precincts). These are within the purview of traffic engineering and planning, where concepts of place and movement and melding.

An example of traffic calming structures featuring engineered stormwater gardens are chicanes [41, 42]. These structures slow traffic by confining the travel lanes. They also feature depressed interiors capturing stormwater which feed garden beds, shrubs and trees creating biophilic systems. Chicanes can be formed using sculpture, plantings or parking to enhance the appearance and function of a street. They are best used on narrow roads, to prevent cars from swinging out to maintain their speed around the bends; narrow, curving roads encourage motorists to drive more slowly and carefully [43].

Energy management

Energy management in urban streets serves multiple functions: helping to cool a city where urban heat island effect is leading to ill health; making walkability easier and hence improving urban economics in the area; and helping to cool the buildings next to the street. In multiple studies, urban greenery has shown cooling capabilities [44–46]. Parks lower the air temperature within their territory, but the impact on the adjacent built environment is limited [47]. Urban tree canopy provides a cooling effect in street canyons [48, 49]; some studies show air temperature under a canopy are reduced by 0.7–1.3 degrees Celsius in the early afternoon [50]. The cooling capacity of a tree canopy depends on its characteristics, as well as the characteristics of the street such as surface materials, geometry, building height and how densely the street is built up. However, at night time the air temperature under the canopy, where the radiating heat is captured, can be 0.5 degrees Celsius higher than in an open space reference point [46].

Biophilic structures installed directly onto buildings include green walls and roofs. By introducing such structures, the air temperature in street canyons can be reduced as well as the demand for cooling and heating of buildings. A multi-case study by Alexandri and Jones [51] was conducted in nine cities to assess the thermal effect of green walls and roofs in urban canyons across different microclimates. The authors concluded that the solar radiation absorbed by the roof and facade surface was reduced by applying greenery, and that the heat fluxes vary on different vegetated surfaces and in different microclimates. The outdoor air temperature and energy savings were measured in nine cities. In Hong Kong the analysis of canyon air temperature showed a decrease by a maximum of 3.9 degrees Celsius, while in hot and arid Riyadh the maximum flux was 18.7 degrees Celsius on the green wall surface. Roof surface temperatures are even more significant. In Mumbai the temperature decreased by 26.1 degrees Celsius and in London the maximum decrease was 19.3 degrees when comparing unvegetated and vegetated rooftops.

Stormwater management

Cities feature vast amounts of impervious surfaces producing significant run-off that needs to be managed. Green infrastructure has been found to retain most of the polluted initial run-off through bio-retention and bio-filtration. Through these two processes, rain water can be permanently retained or temporarily detained. Captured stormwater contributes to groundwater recharge and helps sustain the whole water cycle [36]. Biophilic urbanism not only picks up all these design features, it adds more.

In recent years, biophilic designers have transformed one of the largest impervious areas—roof tops—into intensive and extensive gardens and meadows [52, 53], creating efficient stormwater management systems [54]. Stovin [55] tested green-roof stormwater retention on a small-scale trial and found that the retention capacity was on average 34, and 57% of peak flow run-off.

In another study led by Kew [53], rainfall was shown to have little or no impact on the green wall. Most of the rainfall was blocked by the gutters integrated into the system. In order to improve the efficiency of the green roof and wall systems, the run-off from the roof was collected into cisterns and then used to irrigate the green walls with drip irrigation. Green walls do not directly collect significant amounts of precipitation; however, they are often used to control first stormwater flush. The efficiency of a particular system does not only depend on technological advancement, but also on climatic conditions and the vegetation and growing medium as well as whether the green wall is facing the main weather fronts [56].

Thus, a green roof can be considered an alternative to a conventional stormwater management system and become integrated into the concept of a biophilic street. In an urban setting, a total facade area usually exceeds a roof area; thus, a well-designed green wall could become part of the green-roof stormwater system if that is a desired outcome. With more competition for ground vertical surfaces in urbanised areas, the potential of rooftops and vertical surfaces for stormwater management is significant. The success of green roof and green wall stormwater management can be measured by the increasing number of municipalities, developers, and individuals undertaking this first flush control [53]. A biophilic

street can thus become part of a whole new stormwater management system.

Biodiversity management

Efforts to preserve global biodiversity are frequently centred on saving large remaining natural habitats [57]. However, several studies on urban greenery provide data on biodiversity in parks, gardens, squares, streets and other places where flora and fauna can be found. Urban parks offer refuge to native biota [58] and urban streets also have the ability to support biodiversity [58, 59] by providing food, shelter and breeding sites and facilitating the movement of wildlife.

Significant percentages of animal and plant species, including endangered species, inhabit urban forests. For example, highly urbanised environments have been found to accommodate 20% of the world's avian biodiversity [60]. A study by Threfall [59] showed a strong connection between understorey vegetation and native bird species in Melbourne, Australia.

Innovative structures like green walls and roofs are popular sustainable design interventions due to their ability to cool the building envelope and create aesthetically pleasing facades. However, the structure of a biophilic street with large variations in the height of different vegetation types on various buildings and in the street itself, should support biodiversity in cities at a landscape scale. The design detail of a biophilic street could be used to enable a range of biodiversity goals, for example, by acting as a corridor to facilitate movement [61]. At a local scale, vertical greening systems can be used as means to improve the environmental conditions, with even simple flora assemblages providing habitat for invertebrates [62] as well as nesting, food and shelter resources for urban ornithology [62, 63]. The size of impact on biodiversity from such biophilic street structures is yet to be ascertained, though undoubtedly the plant species introduced will influence the richness of animal species. Whether this could support urban ecological restoration has not been researched at a significant scale [64].

In a study undertaken in Staffordshire, United Kingdom, a number of bird species of conservation concern were reported exploiting and nesting in some newly created green walls and their immediate surroundings [65]. The researchers concluded that encouraging homeowners and businesses to install green walls could be an effective way of providing habitat and resources for birds in an urban environment. This also highlights an important opportunity for urban open space designers and managers to make a positive impact on biodiversity through relatively small and cost-effective improvements in vegetation quality by creating more biophilic streets.

In a study of bio-retention swales undertaken in Australia, researchers observed that the swales presented greater richness and diversity of species than gardens and lawn-type green spaces. Bio-retention swales are vegetated water sensitive urban design (WSUD) structures built to support more sustainable urban infrastructure [66]. This system is increasing in popularity and replacing customarily vegetated areas of streetscapes with sustainable natural assets [67]. It is likely to become a more mainstream design outcome, however, if part of a biophilic street.

Street furniture

The design innovations outlined above comprise building biophilic elements along street spaces and on facades of buildings for a range of reasons. This section focuses on the potential of street furniture, an important element of every street, to fulfil a biophilic function in addition to its usual function.

Urban street furniture is designed and integrated into streets for a range of reasons but rarely for purposes related to biophilic urbanism. This is possible to achieve and likely to work best if its biophilic potential is incorporated into a design from the beginning rather than added after other elements have been considered or are in place. Bus shelters, bicycle stands, street art, play installations and benches have been used in several major cities to support native flora and fauna, facilitate habitation for wildlife and provide various other ecosystem services. So it is possible to add this dimension to a biophilic street.

Maynard Green Street in Seattle, United States, is an example of harnessing urban street furniture to support natural systems. The street was refurbished in 2010 as part of Seattle's Green Street program, which was established to enhance open space and pedestrian circulation. Combining public art with a water filtration system, the Maynard project incorporates rooftop run-off that enters a cistern before flowing down the custom-designed planters. The planters also function as benches for pedestrians ascending and descending the steep street [68].

Another example of innovative street furniture is the CityTree designed by a German start-up, Green City Solutions [69, 70]. Their key aim was to build a street furniture element able to provide air-purifying solutions in a man-made ecosystem. The structure consists of biologically engineered moss and vascular plant species grown using a green wall system. Rainwater is gathered and recycled through the system while irrigating the plants. The efficiency of this street furniture still needs to be tested and proven in multiple locations. However, the company claims that a single CityTree is capable of combating air pollutants as effectively as 275 urban trees at 5% of the cost and requiring 99% less space. They also claim that a single CityTree has the ability to reduce air pollution by 30% within a 164-ft radius. So far, the

CityTree has been tested in several large cities across the globe: Berlin, Paris, Glasgow, Oslo and Brussels [69].

Bus shelters have been included in greening projects in many cities. Green shelter prototypes have been created to provide more inviting and enjoyable experiences while addressing the needs of transit waiting areas. Trials have highlighted the benefits of integrating biophilic design and sustainable transit to lessen the environmental impact of climate change.

The Living Bus Shelter in Minneapolis, United States, was an initiative between the Minneapolis Downtown Improvement District and Metro Transit. The structure was comprised of vertical pallet gardens containing a variety of edible plants. After the installation, commuters were encouraged to explore the plants by touching, smelling, tasting or even taking them home. The data, which emerged in a survey, showed improved transit user experience. All respondents gave positive answers when asked whether they favoured the incorporation of greenery into the shelter. The aesthetic character of the installation was rated nine out of ten and users generally expressed enthusiasm about the greenery and suggested increasing the volume. In the end, 65% of respondents gave the green light to the local authorities to continue reimagining transit shelters through green installations [71].

Other cities, such as San Francisco and Philadelphia in the United States, Sheffield in the United Kingdom, and Eindhoven in Germany, introduced similar programs of greening their transit shelters. The local authorities intended to provide an attractive green space in the unconventional location of concrete dominated urban space. Vegetated roof installations on a bus shelter in Philadelphia aimed to raise awareness about urban stormwater management [72]. In Eindhoven, bus shelter design aspired to perfect integration with the existing city fabric. The green bus stop design was selected through a competition organised by the council [73]. Vegetation installed on public transport shelters is considered to be in a prime position to filter contamination and particulate matter from transport vehicles [35]. These initial attempts to green bus shelters successfully captured the imaginations of city inhabitants while promoting sustainable and feasible innovations.

Activity and education

Gehl Architects identify three types of activities that occur in urban environments: necessary, optional and social activities. Optional activities depend on the quality of a place; the more attractive a place is, the more often pedestrians choose to stroll, play, sit and eat there. The design features of biophilic streets should encourage these optional activities, facilitate community and reinforce the identity of a neighbourhood. The best executed biophilic streets will therefore be full of nature, bringing more people outside and into shared activities. An intense mixture of uses also makes streets safer [5].

When streets function well on an everyday level of biophilic experience, they provide opportunities for activities like teaching, learning and entertainment. Wider streets, like boulevards, provide opportunities for entertainment such as play equipment, art installations, water fountains, games and other foci for social interactions. A good example is found in Montreal, Canada, where a lifeless median of Promenade des Artistes has been transformed into an active space as part of a biophilic street regeneration. Twenty-one multi-coloured, musical swings were installed in order to foster play and social interaction between pedestrians of all ages and backgrounds [74].

Environmental agencies and local councils encourage communities to engage in the renewal and enhancement of urban nature. In 2015, The Environmental Protection Authority (EPA) in South Australia launched the Rain Garden 500 program [75], through which local councils and community groups can apply for funding to build rain gardens. The program helps to improve the quality of stormwater run-off. Another purpose is to educate communities and school children about the impact residents may have on the quality of urban waterways. Information plaques were installed to spread knowledge about the importance of water harvesting projects. Thus, design elements that enable activities and education in a biophilic street are part of the Framework presented in this paper.

The five characteristics of a street that lend themselves to the application of biophilic design elements, as outlined above and in Table 4, will now be discussed in relation to four examples of a street revitalisation project to determine how effectively the proposed Biophilic Streets Design Framework can contribute to creating more biophilic cities with multiple urban benefits.

Potential issues and trade-offs

Potential benefits of the biophilic streets have been presented; however, it is also necessary to address potential issues and trade-offs associated with the proposed concept. Some issues may include a high initial cost of construction, high cost of maintenance and limited on-street parking due to the expansion of green infrastructure within street medians. A higher concentration of plants (native or edible) or rain gardens may produce higher amounts of organic litter, which may become a nuisance to some pedestrians. However, the changing seasons and patina of time—the two biophilic experiences—are achieved, enriching and improving the overall biophilic experience.

Green infrastructure within street medians may generate higher maintenance costs. For example, the

maintenance of green walls and roofs extend the area of greenery expected in conventional streets, which may result in additional costs.

The maintenance costs could be shared between the local authority and the residents (private and commercial) of a biophilic street. A successful maintenance sharing program can be found in Portland, Oregon. The Green Street Stewards were volunteers who were responsible for occasional removal of sediments, collection of organic matter and rubbish from the planters and watering [76]. By facilitating the stewardship program, the city helped to create bonds between the residents and the local urban nature, at the same time reducing the cost of maintaining the streets.

Research into costs and benefits of selected street elements, such as trees, can be found in the scientific literature [77, 78]; however, a biophilic street—as a green infrastructure project—would require a holistic economic analysis to prove the feasibility of a proposed design scheme.

Analysis of the selected streets

Four illustrative examples of a street revitalisation project were selected for analysis through the lens of the proposed Biophilic Streets Framework: a former urban highway in Vitoria-Gasteiz, Spain; the streets renewal project in Downtown Berkeley and SW Montgomery Green Street in Portland, United States; and the Green your Lane project in Melbourne, Australia. The selected streets serve as examples of a diverse approach to street design using multiple tools and strategies to achieve high performing biophilic public spaces. They represent different types of biophilic streets in terms of their hierarchy and their functions. Their biophilic street features are summarised in Table 5 using each of the Framework's six design characteristics.

Gasteiz Hiribidea in Vitoria-Gasteiz, Spain

Vitoria-Gasteiz, the capital city of the Basque Country, has been committed to the principles of sustainable urban development for many years. In 2013, Vitoria-Gasteiz joined the league of biophilic cities with a showcase of successful projects and interventions fulfilling the biophilic urbanism agenda [7, 8]. The urban greenery of Vitoria-Gasteiz features 50,000 plants composed of 381 species of trees and shrubs, including tree-lined streets and avenues connecting urban biodiversity [79]. One of the main roads, Gasteiz Hiribidea, underwent a major revitalisation and became an example of good practice for other cities to follow. In the past, the street was an eight-lane highway, but after a major redesign, it now features a naturalised stream and an abundance of greenery including trees, a grassed tram line, two cycle tracks and broad sidewalks. The naturalised stream, which was once channelled under the streets, now runs along the pavement. It features native aquatic and riparian vegetation bordered by a reinforced embankment. The stream provides habitat to small animals for feeding, breeding and shelter, enhancing local urban biodiversity (Fig. 1). Together with the large green envelope of the Palace of Europe, the stream creates a biodiversity hotspot in the city centre providing habitat to over 70 species of butterflies [7]. Flowering perennials and annuals create a vertical botanical garden which also serves as an educational centre bringing local nature closer to city dwellers. The street, which once had no room for nature, now abounds with it and its natural processes are available to observe and interact with it on a daily basis. This revitalisation project reinforces the cultural value of the place while also promoting environmental awareness by building a relationship between citizens and nature.

So far, the City of Vitoria-Gasteiz has developed a plan for improving bio-capacity, biodiversity and urban landscape. The most important project is the creation of an external and internal green belt and the activation of the potential of urban green spaces connected by a network of green and biophilic streets, avenues, wooded garden walks and urban trails. The connection between innovative biophilic structures and traditional greenery secures the effectiveness of the urban green network to perform ecological functions and increase biodiversity in the city. The biophilic street in Vitoria-Gasteiz is emerging as a major part of the city's biophilic urbanism.

Downtown Berkeley, United States

The aim of the streets renewal project in Downtown Berkeley was to provide the usual functions of a street, but to add ecological features in an innovative way on a limited budget. In 2012, the City of Berkeley issued The Street & Open Space Improvement Plan (SOSIP) to present a shared vision for the future of Downtown Berkeley's public realm (Fig. 2) [80]. The revitalisation project included Shattuck Avenue and Park Blocks, Shattuck Square, University Avenue, Centre Street Plaza, Greenway, Hearst Street and Ohlone Greenway. A number of sustainability goals were established featuring biophilic attributes and experiences. The main objectives of the major projects were walkability, place-making, public life, sustainability, health and comfort. To achieve these a community engagement process was undertaken [6].

The strategies employed in the Downtown project were to create a more vibrant, attractive and memorable destination. The information gathered during community consultations informed the focus of the project: public life and the provision of space for a myriad of activities—social, cultural and business—engaging all residents and visitors. The leading

Table 5 Application of the framework for biophilic streets design in four analysed street projects

Functions of a biophilic street	Biophilic design elements applied to analysed street projects			
	Gasteiz Hiribidea, Vitoria-Gasteiz, Basque Country, Spain	Downtown in Berkeley, California, USA	SW Montgomery Street, Portland, Oregon, USA	Green Lanes, Melbourne, Victoria, Australia
Traffic planning	- prioritizing pedestrians and cyclists; - enhancing facilities for transit; - slowing traffic.	- prioritizing pedestrians and cyclists; - enhancing walkability standards; - reducing existing traffic lanes; - lowered traffic speed.	- prioritizing pedestrians and cyclist (kerb-less paving); - narrowing existing traffic lanes; - lowered traffic speed; - sections of the street closed to traffic.	- limited traffic (local only) - shared space between pedestrian and vehicles.
Energy management	- energy reduction due to ecological runoff treatment; - insulation capabilities of green walls and roofs systems; - heat island effect mitigation by tree canopies, landscaping and waterbodies.	- energy reduction due to ecological runoff treatment; - insulation capabilities of green walls and roofs systems; - heat island effect mitigation by tree canopies, landscaping and waterbodies.	- energy reduction due to ecological runoff treatment; - insulation capabilities of green walls and roofs systems; - air temperature regulation through landscaping.	- energy reduction through 'green insulation'; - heat island effect mitigation through landscaping and miniature raingardens.
Storm water management	- retention in underground cisterns; - Infiltration via permeable surfaces - purification using bio-filters (plants); - recycling via green wall and roof systems; - bio-filtration through daylighted stream.	- retention in underground cisterns; - Infiltration via permeable surfaces; - retention and bio-filtration through swales, raingardens; - purification using bio-filters (plants); - recycling via green wall and roof systems; - bio-filtration through daylighted stream.	- Infiltration via permeable surfaces; - retention and bio-filtration through stormwater planters and raingardens; - purification using bio-filters (plants); - recycling via green wall and roof systems.	- Infiltration via permeable surfaces; - retention and bio-filtration through raingardens; - recycling via green wall systems.
Biodiversity management	- green walls, roof and living stream designed for biodiversity enhancement and ecological restoration; - daylighted and restored stream with riparian plants provide habitats for wildlife and facilitate species migration.	- green walls designed for biodiversity enhancement and ecological restoration; - daylighted and restored stream with riparian plants provide habitats for wildlife and facilitate species migration.	- green walls designed for biodiversity enhancement and ecological restoration; - use of native species - green corridors connect fragmented green areas; - raingardens provide habitat for wildlife.	- green walls, planters, miniature raingardens designed for biodiversity enhancement and ecological restoration; - habitats for wildlife and facilitate species migration.
Street furniture	- integrated street furniture; tree pits and sittings expressing ecological sensitivity;	- parklets in parking spaces; - natural buffer between sidewalks and traffic; - public art supporting environmental awareness; - permeable paving facilitating rainwater infiltration.	- green wall and roof systems; - permeable paving facilitating rainwater infiltration.	- planter-boxes with irrigation systems; - green wall system hanging baskets and miniature raingardens; - permeable paving facilitating rainwater infiltration.
Activity and education	- activity features for kids: sculptures, water features; - informative design of green walls and roofs; - interpretive plates and signs; - exposed ecological systems.	- interactive play equipment; - interpretive plates and signs; - exposed ecological systems; - parklets and temporary installations.	- interpretive plates and signs; - exposed ecological systems; - green infrastructure serves educational and research purposes; - activation of shopfronts supports community living.	- green infrastructure serves educational and research purposes.

aspiration was to establish public green open spaces for residents of different ages and abilities. To meet the objectives, the city established the design criteria, which required all the design features to be used consistently along the nominated streets reflecting traditional character compatible with Downtown historic assets. As a result, all place-making amenities, including public art, were expected to provide a sense

Fig. 1 Living stream opposite the Palace of Europe in Vitoria-Gasteiz, Spain. Source: Agata Cabanek

of place and evoke local heritage values as well as exhibiting biophilic features.

The biophilic elements included temporary planted installations, such as parklets in parking spaces, to improve and promote pedestrian-oriented activities rather than car use. Parklets help to raise awareness of local nature if their ecological design underpins the concept. Their presence may also lead to the reconsideration of the public realm; parklets could become permanent features evoking a biophilic sense of place.

To achieve the walkable city standards, the city council considered improvements supporting car-free living. One of the solutions was to provide more accessible transit options. To make streets more inviting and attractive, the traffic lane widths were reduced, the sidewalks were widened and bicycle lanes were introduced. The biophilic element was to provide extra space for landscaping buffers between pedestrians and traffic.

Bio-retention swales and rain gardens with riparian landscaping were used in some streets to treat rainwater run-off, thereby improving watershed conditions. The program also included daylighting of Strawberry Creek between Shattuck Square and BART Plaza. Daylighting the creek provided another opportunity to educate the residents about the ecological and biophilic values of natural waterbodies in the urban environment.

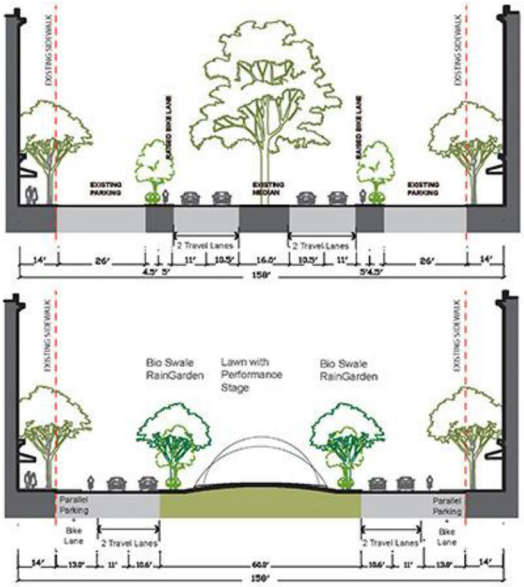
Living walls and roofs installed on the buildings bordering the streets provided green infrastructure services and served as aesthetic features enhancing the image of Downtown as an eco-destination. Accessible educational and recreational features in the form of interpretive plates, boards and interactive play equipment were included to educate people about natural systems and their ecological and economic values.

The local government initiated the Downtown revitalisation project which aimed at creating an Art and Theatre District. The funds to finance the public art projects came from many sources – certificates of participation, bond funds, capital, and federal transportation funds. Additionally, the town representatives were also able to secure private funds by consulting the local property and business owners. The money raised to be invested in public art was partially used to revitalise the local streets. Another important source of funding came from the earthquake retrofit bond launched in 1996, which added $4 million for enhancing the streetscapes. As a result, the revitalisation of the Downtown project delivered many biophilic elements to the streets and created attractive, walkable restorative public spaces [81].

SW Montgomery street in Portland, United States

In 2004, Portland City Council approved the Green Street Policy Goals program through which they committed to promote and incorporate the use of green street facilities in public and private development. One of the first streets to undergo green transformation was SW Montgomery Street. The changes demonstrated an emerging new urban street design approach. This multisectional revitalisation project incorporated strategically designed green infrastructure and public transportation. SW Montgomery Street is considered to be Portland's boldest and most innovative green street project and has received national and international recognition [82]. The main planning strategy was to activate the neighbourhood, build community culture, enhance the pedestrian experience and showcase the sustainability agenda in the downtown area of the city. The concept applied, which included substantial biophilic street elements, was to become a new place-making model for other downtown

Source: cityofberkeley.info



Source: Taecker Planning and Design

Fig. 2 SOSIP masterplan and section of street design integrating greeneries and multiple functions

streetscape projects in Portland. Street design goals included creating a pedestrian-oriented streetscape that incorporated a variety of green infrastructure solutions such as stormwater planters and swales (Fig. 3), green walls and roofs, and kerbless street design to offer a variety of sensory experiences throughout the seasons.

The biophilic street concept exemplified by SW Montgomery Street, emphasised pedestrian and bicycle travel over vehicular access. Bicycle and pedestrian safety became a priority, and in order to achieve it travel lanes were narrowed, some blocks were closed to through traffic and speed limits were lowered. The biophilic features could then be added to a kerb-less street with merged sidewalks that incorporated planting and swales to absorb stormwater [83].

Stormwater planters and swales also became educational amenities for the local communities. Since SW Montgomery Green Street runs through the Portland State University campus, students are encouraged to take part in monitoring the performance of the green infrastructure. To facilitate the involvement of local citizens, public education about the corridor was incorporated into the design in the form of interpretive signage.

The project also proposed the installation of green walls and roofs on new development buildings. Stormwater from new building facades was directed into the stormwater planters to demonstrate innovative ways of stormwater management.

This project demonstrates how a busy urban street can be re-designed to improve ecological conditions, foster environmental learning, support community identity and neighbourhood engagement and maintain healthy business districts. The street delivers spaces for public interaction and serves as a transportation corridor whilst achieving much more because of its biophilic elements [84].

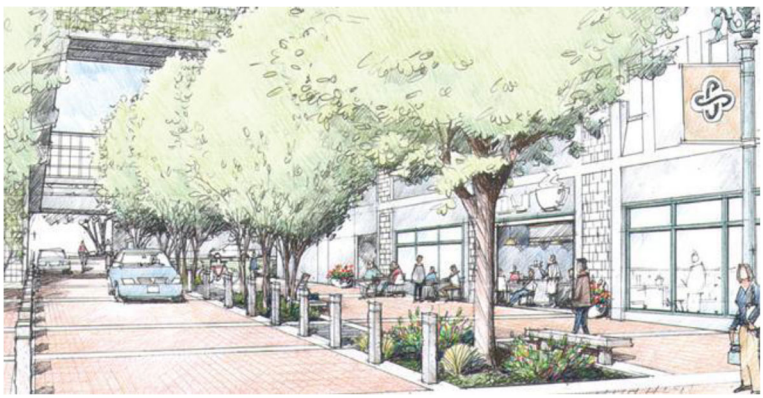


Fig. 3 SW Montgomery Street. Shared space with stormwater swales. Source: Nevue Ngan Associates

Green lanes in Melbourne, Australia

The rejuvenation and revival programs of lanes and alleys have emerged in many cities such as Austin, Chicago, Montreal, San Francisco, Sydney and Melbourne. Although the programs differ in objectives, there is an increasing use of biophilic elements that enable multiple extra objectives through ecosystem services, aesthetics and social life. The example chosen to illustrate this is from Melbourne.

In 2015, City of Melbourne established the Green Your Laneway program to encourage the transformation of Coromandel Place, Guildford Lane, Katherine Place and Meyers Place (Fig. 4) as replicable exemplars [85, 86]. As a part of the program, an interactive map was developed to mark the preselected laneways with strong potential for green transformation based on their local micro-climatic conditions and physical qualities. The program involved strong community engagement to ensure later community ownership of the transformed lanes.

Four lane typologies were selected: vertical gardens, forest lanes, park lanes and farm lanes. In this program, greening mainly meant planting tough ornamentals and establishing vegetable gardens to be cultivated by local residents. Elements such as window boxes, planter boxes with climbers, hanging baskets and miniature rain gardens were proposed (Fig. 5). The more spatially-demanding biophilic design elements involving water were not considered in the narrow laneways due to site constraints.

The planting strategies were designed to improve biodiversity, provide habitat for wildlife, filter pollution from the air and divert some stormwater run-off despite the small size of the gardens due to the restricted space.

Fig. 4 Meyers Place in Melbourne. Source: https://participate.melbourne.vic.gov.au/greenlaneways

Fig. 5 Design concept for Guilford Lane in Melbourne**.** Source: Source: Agata Cabanek

Other environmental benefits, such as a reduction of carbon emissions and mitigation of urban heat island effect through 'green insulation', are also expected.

A range of social and economic benefits were projected by the council. The vision for the revitalisation of the lanes was to transform them from waste areas to useable public spaces. The lanes were rejuvenated to provide pleasant walkways and encourage people to spend time outdoors and engage in social activities. The Biophilic Streets Design Framework was almost completely implemented in terms of biophilic design elements, showing how much can be achieved in urban regeneration if these are central considerations in street rejuvenation or retrofit.

Several economic benefits are expected due to the activation of the lanes: increase in property values, increase in useable green outdoor spaces, extended life-span of permeable surfaces and savings on heating and cooling [87].

All four analysed examples of a street revitalisation project show multiple urban benefits which are summarised in Fig. 6. The many additional outcomes that surpass the usual functions of streets are evident.

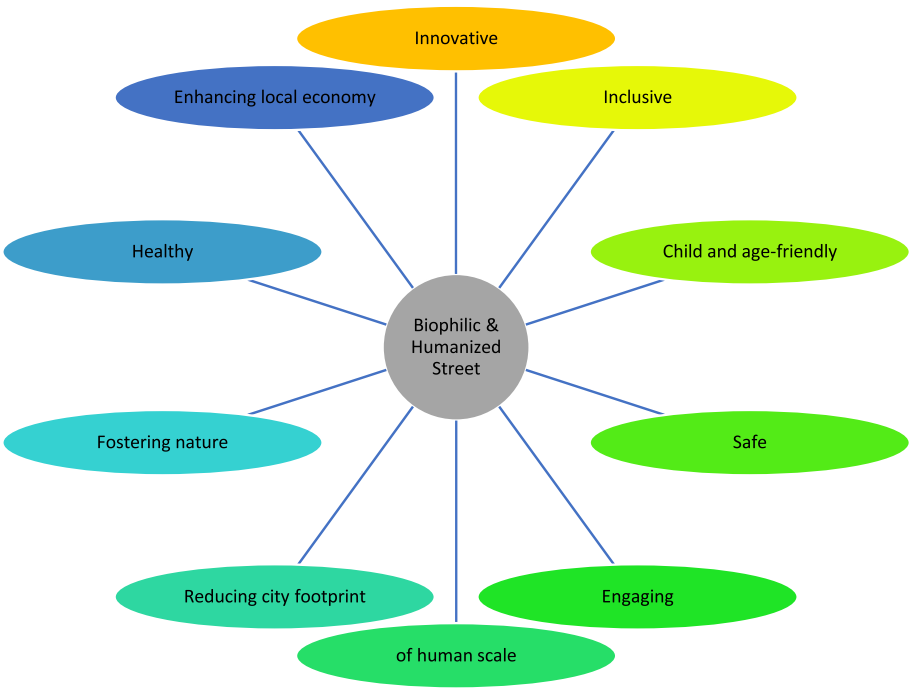


Fig. 6 The multiple urban benefits of a Biophilic Street

Cities would derive substantial value from considering biophilic enhancements in their streets as part of their future plans.

Conclusions

The Design Framework for Biophilic Streets, developed through this research, suggests that much more can be achieved within a city if streets are given biophilic design elements absent in traditional streets. Much can be achieved by adding the biophilic elements of green walls, green roofs and green balconies to building envelopes. Considerable benefit is also possible by adding elements to existing urban streets and road reserves: tree pits, street trees, linear gardens, pocket parks, bioswales, rain gardens, daylighting streams, and biophilic elements integrated with street furniture. The value of all of these biophilic features can be enhanced by incorporating educational and activity functions that can be seen and experienced in the street.

The four analysed street examples demonstrate how biophilic streets can be built in different climates, types of cities, urban structures, and levels of development. In the four analysed projects, the streets illustrated most of the biophilic elements in the Framework, though spatial limitations in high density urban fabrics do limit most of the water-oriented biophilic design elements. However, the majority of the examples were in medium density areas and were able to demonstrate that biophilic design elements can be incorporated into streets and create significant value outcomes in a multiplicity of economic, social and environmental ways. The value in humanising streets has been well established and it should now be possible to add the design dimensions of biophilic streets, as set out in the Biophilic Streets Design Framework. This is likely to enable a broader perspective on the value of streets in cities.

The Biophilic Streets Design Framework could be used by policy-makers and designers to move from the theoretical and imaginative biophilic urbanism discourse to real-life projects and urban interventions. When applied in conjunction with other design strategies and policies, for example, water-sensitive, biodiversity-sensitive, regenerative, resilient or ecological urban design, the Framework could help to improve urban infrastructure so it delivers restorative and health-promoting outcomes across any city.

Biophilic urbanism is becoming a major policy area for delivering tangible benefits to cities and their populations. This paper has suggested that by transforming urban streets into biophilic streets it is possible to add an extra dimension to biophilic urbanism. The biophilic street concept integrates the ideas advocated by Jane Jacobs and Jan Gehl who have demonstrated that people-oriented streets contribute to a community's economic and social enhancement by integrating environmental approaches into the functional design of streets.

Future research is needed to monitor and quantify the performance of biophilic streets in addressing the adverse effects of climate change, environmental degradation and biodiversity loss; as well as how it can be cost-effective.

Acknowledgements

Not applicable.

Authors' contributions

Conceptualisation, AC; Methodology, AC,PN; Investigation, AC; Analysis AC, MZB; Original draft preparation, AC; Review & Editing PN, AC, MZB. All authors read and approved the final manuscript.

Funding

This research funded by the CRC for Low Carbon Living Ltd. supported by the Cooperative Research Centres program, an Australian Government initiative.

Availability of data and materials

The dataset used and analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare they have no competing interests.

Received: 9 October 2019 Accepted: 7 May 2020
Published online: 08 July 2020

References

1. Kostof S. The city shaped: urban patterns and meanings through history. London: Thames and Hudson; 1999.
2. Mumford L. The city in history: its origins, its transformations, and its prospects. New York: Harcourt, Brace & World; 1961.
3. Jacobs J. The death and life of great American cities. New York: Vintage; 1961.
4. Matan A, Newman P. People cities: the life and legacy of Jan Gehl. Washington DC: Island Press; 2016.
5. Gehl J. Cities for people. Washington DC: Island Press; 2010.
6. Kellert SR, Heerwagen J, Mador M. Biophilic design: the theory, science, and practice of bringing buildings to life. Hoboken: Wiley; 2008.
7. Beatley T. Biophilic cities: integrating nature into urban design and planning. Washington, DC: Island Press; 2010.
8. Beatley T. Handbook of biophilic design. Washington, DC: Island Press; 2016.
9. Wilson EO. Biophilia. Cambridge: Harvard University Press; 1984.
10. Kellert S, Calabrese E. The practice of biophilic design. 2015. www.biophilic-design.com. Accessed 16 Sept 2019.
11. Kellert S, Finnegan B. Biophilic design: the architecture of life. A 60-minute video. 2011. www.bullfrogfilms.com. Accessed 17 Sept 2019.
12. Salingaros NA. Biophilia and healing environments: healthy principles for designing the built world. New York: Terrapin Bright Green LLC; 2015.
13. Newman P. Biophilic urbanism: a case study on Singapore. Aust Plann. 2014; 51:47–65.
14. Newman P, Beatley T, Boyer H. Resilient cities: overcoming automobile dependence. Washington DC: Island Press; 2017.
15. Newman P, Jennings I. Cities as sustainable ecosystems. Washington DC: Island Press; 2008.
16. Urlich RS. View through a window may influence recovery from surgery. Science. 1984;224:420–1.
17. Kaplan R, Kaplan S. The experience of nature: a psychological perspective. Cambridge: Cambridge University Press; 1989.
18. Terrapin Bright Green. Fourteen patterns of biophilic design. Improving health & well-being in the built environment. 2012. http://www.terrapinbrightgreen.com/reports/14-patterns/. Accessed 10 Sept 2018.

19. Yuchi W, Sbihi H, Davies H, Tamburic L, Brauer M. Road proximity, air pollution, noise, green space and neurologic disease incidence: a population-based cohort study. Environ Health. 2020;19(1):8.
20. Zelenski JM, Dopko RL, Capaldi CA. Cooperation is in our nature: nature exposure may promote cooperative and environmentally sustainable behaviour. J Environ Psychol. 2015;42:24–31.
21. Cameron J. Educating for place responsiveness: an Australian perspective on ethical practice. Ethics Place Environ. 2003;6:99–116.
22. Mang P, Reed B. Designing from place: a regenerative framework and methodology. Build Res Inf. 2011;40:23–8.
23. Steiner FR, Thompson GF, Carbonell A. Nature and cities. The ecological imperative in urban design and planning. Cambridge: Lincoln Institute of Land Policy; 2016.
24. Hirt S, Zahm D. The urban wisdom of Jane Jacobs. Abingdon: Routledge; 2012.
25. Alexiou-Sparberg A. Jane Jacobs: urban visionary. New Brunswick: Rutgers University Press; 2006.
26. Jacobs J. The economy of cities. New York: Vintage Books; 1970.
27. Leinberger CB. The option of urbanism. Washington, DC: Island Press; 2010.
28. Leinberger CB, Lynch P. Foot traffic ahead: ranking Walkable urbanism in America's largest metros. Washington, DC: George Washington University School of Business, Center for Real Estate and Urban Analysis; 2014.
29. Yigitcanlar T. Making space and place for the knowledge economy: knowledge-based development of Australian cities. Eur Plan Stud. 2010;11:1769–86.
30. Newman P, Kenworthy J. The end of mobile dependence. How cities are moving beyond car-based planning. Washington, DC: Island Press; 2015.
31. Gehl J. Life between buildings. Using public space. Washington DC: Island Press; 2011.
32. Gehl J, Kaefer L, Reigstad S. Close encounters with buildings. Urban Des Int. 2006;11:29–47.
33. Fu Y, Zhang X. Planning for sustainable cities? Comparative content analysis of the master plans of eco, low-carbon and conventional new towns in China. Habitat Int. 2017;63:55–66.
34. Zhang X, Li H. Urban resilience and urban sustainability: what we know and what we do not know? Cities. 2018;72:141–8.
35. NACTO. Global street design guide. Washington DC: Island Press; 2017.
36. Girling C, Kellett R. Skinny streets and green neighbourhoods: design for environment and community. Washington DC: Island Press; 2005.
37. Diane Toomey. Designing for the urban landscape to meet 21st century challenges. 2012. http://e360.yale.edu/features/martha_schwartz_urban_landscape_designs_to_meet_21st_century_challenges. Accessed 12 Aug 2018.
38. Burton E, Mitchell L. Inclusive urban design: streets for life. Oxford: Architectural Press; 2006.
39. Carmona M, Heath T, Oc T, Tiesdell T. Public places urban spaces. Oxford: Taylor & Francis Ltd; 2010.
40. Newman P, Kenworthy J. Sustainability and cities. Washington DC: Island Press; 1999.
41. Course D. Traffic calming: a social issue. Bull Sci Technol Soc. 2004;24:138–44.
42. Grana A, Guerrieri M. Exploring effects of area-wide traffic calming measures on urban road sustainable safety. J Sustain Dev. 2010;3:38.
43. Traffic calming 101. 2008. https://www.pps.org/reference/livememtraffic/#CHICANES. Accessed 17 Sept 2019.
44. Wong NH, Chen Y. The role of urban greenery in high-density cities. In: Ng E, editor. Designing high-density cities for social & environmental sustainability. Routledge; Abingdon 2010. p. 227–262.
45. Ng E, Chen L, Wang Y, Yuan C. A study on the cooling effects of greening in a high-density city: an experience from Hong Kong. Build Environ. 2012;47:256–71.
46. Chiesura A. The role of urban parks for the sustainable city. Landsc Urban Plan. 2004;68:129–38.
47. Bowler D, Buyung-Ali L, Knight TM, Pullin AS. Urban greening to cool towns and cities: a systematic review of the empirical evidence. Landsc Urban Plan. 2010;97:147–55.
48. Norton B, Coutts A, Livesley S, Harris R, Hunter A, Williams N. Planning for cooler cities: a framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landsc Urban Plan. 2015;134:127–38.
49. Loughner C, Allen D, Zhang D, Pickering K, Dickerson R, Landry L. Roles of urban tree canopy and buildings in urban Heat Island effect: Parametrization and preliminary results. J Appl Meteorol Climatol. 2012;51:1775–93.
50. Souch CA, Souch C. The effects of threes on summertime below canopy urban climates: a case study Bloomington, Indiana. J Arboric. 1993;19:303–12.
51. Alexandri E, Jones P. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Build Environ. 2008;43:480–93.
52. Getter K, Rowe B. The role of extensive green roofs in sustainable development. HortScience. 2006;41:1276–85.
53. Kew B, Pennypacker E, Echols S. Can green walls contribute to Stormwater management? A study of cistern storage green wall first flush capture. J Green Build. 2014;9:85–99.
54. Dietz ME. Low impact development practices: a review of current research and recommendations for future directions. Water Air Soil Pollut. 2007;186:351–63.
55. Stovin V, Vesuvian G, De-Ville S. Defining green roof detention performance. Urban Water J. 2017;14:574–88.
56. Weinmaster M. Are green walls as 'green' as they look? An introduction to the various technologies and ecological benefits of green walls. J Green Build. 2009;4:3–18.
57. Alvery AA. Promoting and preserving biodiversity in the urban forest. Urban For Urban Green. 2006;5:195–201.
58. Oprea M, Mendes P, Vieira T, Ditchfield A. Do wooded streets provide connectivity for bats in an urban landscape? Biodivers Conserv. 2009;18:2361–71.
59. Threlfall CG, Mata L, Mackie JA, Hahs AK, Stork NE, Williams NSG, Livesley SJ. Increasing biodiversity in urban green spaces through simple vegetation interventions. J Appl Ecol. 2017;54:1874–83.
60. Katti M. Biodiversity can flourish on an urban planet. 2014. http://theconversation.com/biodiversity-can-flourish-on-an-urban-planet-18723. Accessed 16 Sept 2019.
61. Angold P, Sadler J, Hill M, Pulin A, Rushton S. Biodiversity in urban habitat patches. Sci Total Environ. 2006;360:196–204.
62. Francis R, Lorimer J. Urban reconciliation ecology: the potential of living roofs and walls. J Environ Manag. 2011. https://doi.org/10.1016/j.jenvman.2011.01.012.
63. Collins R, Schaafsmab M, Hudsona MD. The value of green walls to urban biodiversity. Land Use Policy. 2017;64:114–23.
64. Williams NSG, Lundholm J, MacIvor JS. FORUM: do green roofs help urban biodiversity conservation? J Appl Ecol. 2014;51:1469–759.
65. Chiquet C, Dover JV, Mitchell P. Birds and the urban environment: the value of green walls. Urban Ecosyst. 2013;16:453–62.
66. Dahlenburg J, Birtles P. All roads lead to WSUD: exploring the biodiversity, human health and social benefits of WSUD. Barton: Engineers Australia; 2012. p. 94.
67. Kazemi F, Beecham S, Gibbs J. Streetscape biodiversity and the role of bioretention swales in an Australian urban environment. Landsc Urban Plan. 2022;101:139–48.
68. Williams DB. Seattle walks: discovering history and nature in the city. Washington, DC: University of Washington Press; 2017.
69. Shueh J. Startup invents a bench that can cut air pollution by up to 30 percent. 2016. http://www.govtech.com/products/Startup-Invents-Bench-Reduces-Air-Pollution.html. Accessed 16 Sept 2018.
70. Pultarova T. Built environment - pollution: inspired ideas for purer air. Eng Technol. 2017;12(4):46–7. https://doi.org/10.1049/et.2017.0425. Accessed 16 Sept 2019.
71. Gallas T, McKennan P. The living bus shelter (Report No. 37). 2016. https://www.mplsdowntown.com/wp-content/uploads/2017/03/37_TheLivingBusShelter_FinalReport.pdf. Accessed 15 May 2019.
72. Yuka Yoneda. Philadelphia plants its very first bus stop green roof! 2011. https://inhabitat.com/philadelphia-plants-its-very-first-bus-stop-green-roof/#ixzz2lZueshlB. Accessed 10 May 2019.
73. WVTTK Architects. Living bus shelter in eindhoven is overflowing with plants. 2012. https://inhabitat.com/wvttk-architects-living-bus-shelter-in-eindhoven-is-overflowing-with-plants/ Accessed 10 May 2019.
74. A street you go to, not just through: principles for fostering streets as places. 2015. https://www.pps.org/reference/8-principles-streets-as-places/. Accessed 18 Sept 2019.
75. The environment protection authority in South Australia. Rain garden program wraps up. 2018. https://www.epa.sa.gov.au/articles/20201518/11/28/rain_garden_program_wraps_up. Accessed 17 Sept 2019.

76. City of Portland. Green street steward program. https://www.portlandoregon.gov/bes/52501. Accessed 25 Jan 2020.
77. Soares A, Rego F, Mcpherson E, Simpson J, Peper P, Xiao Q. Benefits and costs of street trees in Lisbon, Portugal. Urban Forestry Urban Green. 2011; 10:69–78.
78. Donovan G, Butry D. Trees in the city: valuing street trees in Portland, Oregon. Landsc Urban Plan. 2010;94(2):77–83.
79. Ayuntamiento de Vitoria-Gasteiz. Anuario estadístico. 2011. https://www.vitoria-gasteiz.org/wb021/was/contenidoAction.do?idioma=es&uid=_7d232eb4_11e86578bd6__7feb. Accessed 14 Jan 2020.
80. City of Berkeley. Downtown streets & open space improvement plan. 2012. https://www.cityofberkeley.info/ContentDisplay.aspx?d=47724. Accessed 10 Jan 2018.
81. Kemp RL. Community renewal through municipal investment, a handbook for citizens and public officials. Jefferson: McFafland & Company; 2015.
82. American Society of Landscape Architects. SW Montgomery Street: connecting the West Hills to Willamette River. 2012. https://www.asla.org/2012awards/572.html. Accessed 17 Sept 2019.
83. Nevue Ngan Associates. SW Montgomery Street: connecting the West Hills to Willamette River. 2009. https://www.pdx.edu/campus-planning/sites/www.pdx.edu.campus-planning/files/2009_MontgomeryGreenStreet_Plan%20%281%29.pdf. Accessed 10 Sept 2019.
84. Rottle N, Yocom K. Basics landscape architecture 02: ecological design. Lausanne: AVA Publishing SA; 2010.
85. Melbourne's first green laneway unveiled. Construction Engineering Australia, 2017;5(3):23. https://search.informit.com.au/documentSummary;dn=249264647527662;res=IELENG. ISSN: 2204–7247. Accessed 17 Sept 2019.
86. City of Melbourne. Laneway visions. Greening map and laneway concepts. https://participate.melbourne.vic.gov.au/greenlaneways/laneway-visions. Accessed 17 Sept 2019.
87. City of Melbourne. Greening laneways. https://www.melbourne.vic.gov.au/community/greening-the-city/green-infrastructure/pages/greening-laneways.aspx. Accessed 17 Sept 2019.

Publisher's Note

Appendix F: Publication 4

Publication 4

Cabanek, A., Zingoni de Baro, M. E., Byrne, J., & Newman, P. (2021). Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia. *Sustainability*, *13*(10), 5461. http://dx.doi.org/10.3390/su13105461

sustainability

MDPI

Article

Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia

Agata Cabanek *, Maria Elena Zingoni de Baro, Joshua Byrne and Peter Newman

Curtin University Sustainability Policy Institute, Curtin University, Kent Street, Bentley, WA 6102, Australia; mariela@integral.info (M.E.Z.d.B.); joshua.byrne@curtin.edu.au (J.B.); p.newman@curtin.edu.au (P.N.)
* Correspondence: agata.cabanek@gmail.com

Abstract: The main purpose of this paper is to demonstrate how the old modernist engineering technologies, such as single purpose stormwater infiltration basins, can be transformed into quality environments that integrate ecological and social functions and promote multiple sets of outcomes, including biodiversity restoration, water management, and cultural and recreational purposes, among other urban roles. Using the principles and theories of biophilic urbanism, regenerative design, and qualitative inquiry, this article analyzes and discusses the actors, drivers, strategies, constraints, and values motivating the stakeholders to reinvent Perth's stormwater infrastructure through two local case studies. The "WGV sump park" was developed through a public-private partnership, including professional consultants with community input, and the "Green Swing sump garden" was an owner-builder community-driven project involving volunteers, who maintain it. The results of this research suggest that both projects are successful at managing stormwater in a way that creates multiple community and biodiversity benefits. Communities could gain improved access to nature, social interaction, health, and well-being if local governments support these alternative approaches to regenerate underutilized stormwater infrastructure by promoting biophilic interventions. Mainstreaming this design approach identified some issues that may arise during the implementation of this biophilic urban approach, and the paper suggests ways to enhance the wider delivery of regenerative and biophilic design into urban planning, involving volunteer delivery and maintenance for small scale projects and fully professional assessments for large scale projects.

Keywords: biodiversity; biophilic design; regenerative design; stormwater management

Citation: Cabanek, A.; Zingoni de Baro, M.E.; Byrne, J.; Newman, P. Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia. *Sustainability* **2021**, *13*, 5461. https://doi.org/10.3390/su13105461

Academic Editor: Thomas Panagopoulos

Received: 7 April 2021
Accepted: 8 May 2021
Published: 13 May 2021

1. Introduction

Urban life is being increasingly affected by rising temperatures, variances in rainfall rates, and more frequent natural disasters, such as floods, droughts, and fires [1,2]. These issues impact not only human populations but also natural environments, resulting in loss of biodiversity. There is an urgent need to develop strategies that enhance urban livability while promoting ecological restoration and preservation. Integrating nature into cities is not only beneficial to maintain biodiversity but also ensures the multiple health benefits that nature provides to humans. Quality green spaces and biophilic places are known to enhance human health and well-being, provide ecosystem services [3,4] and show positive, measurable effects of human interaction with biota in urban environments [5–8].

Such an approach to natural systems in urban areas is applied in this paper to the practice of urban stormwater management. Stormwater management, like other aspects of urban planning and infrastructure provision from the 1940s, is subject to modernist ideals of uniform engineering that have little concern for the local place history, heritage, and biodiversity [9,10]. In Perth, the result was an approach that created uniform sumps that were fenced off and served only a simple function of stormwater management. Two such sumps that have been through a regenerative process are examined to see whether their

goals have been achieved of biodiversity regeneration and local community benefit, as well as enabling good stormwater management. As such, it aims to make a comment about the benefits of regenerative design over modernist design.

The city of Perth, with around 2 million people, is a low-density modern city based on a coastal sand plain, where stormwater is often managed using Stormwater Infiltration Basins (SIBs). Metropolitan Perth has a high number of SIBs, including one type locally called "a sump" (for example, Figure 1). A sump is a local name for an infiltration-retention basin where the stormwater is retained and allowed to infiltrate into an unconfined superficial aquifer. Sumps are typically designed as a 'steeply graded rectangle with an inflow at their base' [11] and differ from more contemporary infiltration basins, which may be more thoughtfully integrated into an amenity landscape and can even include a bio-filtration function [12]. Sumps are a common landscape feature across metropolitan Perth and are often required to be fenced because of the potential for rapid stormwater inflow during heavy rainfall events [13]. Although sumps efficiently perform their function in urban stormwater infrastructure, they have not been valued for their potential social-ecological role. This paper seeks to examine two sumps that have been upgraded in Perth to facilitate their roles in urban biodiversity and local livability, as well as being suitable for stormwater management. The examples become model interventions for how creative biophilic initiatives in cities may contribute to the aforementioned goals.

Figure 1. WGV sump prior and after redevelopment. Credit: JBA.

Using the principles and theories of biophilic urbanism and regenerative design, this article analyzes and discusses two local case studies: the "WGV sump park" in White Gum Valley and the "Green Swing sump garden" in Lathlain, Western Australia. A framework was then developed to help understand the actors, drivers, strategies, constraints, and values motivating the stakeholders to reinvent Perth's stormwater infrastructure. The analysis of the case studies aims to identify issues that may arise during the implementation of biophilic urbanism initiatives and suggest ways to enhance the potential benefit of integrating concepts of regenerative and biophilic design to urban planning and design.

1.1. Theoretical Background

Biophilic urbanism and regenerative design approaches serve to reconnect urban citizens with nature [5,14]. Biophilic interventions facilitate access to nature through the creation of abundant green environments in cities, between and on buildings, providing health and wellbeing to their users and residents [5,8,9]. Regenerative design promotes positive contributions that can heal and improve place conditions, both in their social and biophysical aspects, keeping the system thriving [15–17]. The regenerative design approach sees the integration of humans and their activities with other forms of life in a harmonious and mutually beneficial manner as the core principle in mitigating the threats to sustainability and as a leading pathway to 'restoring the inherent regenerative capacity of natural and social living systems' [18]. Regenerating open spaces is an appropriate pathway to making cities and neighborhoods more livable, not only in the physical aspect but psychologically, as well. It can be achieved by creating biophilic environments that improve livability through the access to nature in attractive open spaces in local areas of cities. The biophilic environments can be created by deploying a variety of urban nature-based solutions, such as pocket parks, community gardens, rainwater gardens, living streams, and green streets [6,19,20].

The benefits from contact with nature are crucial for human well-being but also depend on repeated experiences because, to be functional, it has to be nurtured and developed [7,21,22]. Beatley [6] (p. 154) calls this frequent contact with natural environments 'a daily dose of nature'. He explains that biophilic urbanism interventions provide opportunities for fulfilling experiences of nature, creating green urban spaces for easy and frequent access to nature, and consequently bolstering the reconnection of a city and nature. Besides the human-centered benefits, biophilic urbanism can contribute to the urban and regional regeneration of the ecosystems and biodiversity by restoring or creating new habitats for natural systems [23,24]. As Kellert and Calabrese [19] (p. 11) put it:

> *'Multisensory encounters with nature in the built environment can greatly contribute to comfort, satisfaction, enjoyment, and cognitive performance, and when feasible, should be encouraged'.*

Both biophilic and regenerative design promote an emotional attachment to particular settings and places, encouraging positive interactions between people, nature, and their places that enable a sense of belonging to and responsibility for human and natural communities and their health and wellbeing [25].

Regenerative design seeks to promote conditions that are conducive to life, helping living systems to recover their capacities of re-organizing and regenerating themselves, leading to the wider regeneration of built environments and communities [15,26,27]. These social-ecological approaches to the design of built environments are part of the concept of regenerative sustainability [16,28,29]. The built environment is seen as feasible to be restored and regenerated through the implementation of 'localised ecological design and engineering practices rooted in the context and its social-ecological narratives' [28].

The regeneration and repurposing of storm-water infiltration basins or sumps appear to fit within these social-ecological approaches.

1.2. Location of the Case Studies

Perth is the capital city of Western Australia, with a Mediterranean climate type along the coast. It is set within an ancient landscape and it is considered a biodiversity hotspot [30], which is threatened by urban sprawl [9]. Perth is situated on the Swan Coastal Plain with a groundwater system comprised of two principal aquifers, namely, Gnangara and Jandakot. Those two mounds provide Perth with potable water and also support a vast network of lakes and wetlands. The sandy soils of the Coastal Plain are highly permeable and allow for rapid stormwater infiltration and recharge of the underground aquifers. A system of soak wells and open drainage sumps enables on-site stormwater infiltration in metropolitan Perth [12,31] and provides favorable conditions supporting natural habitats in the urban environment.

The importance of natural habitats within the urban fabric and nearby regional spaces has been recognized for most of the city's history [32,33]. The growing global awareness of biodiversity issues, for example, the Convention on Biological Diversity (CBD) and the associated Aichi Target 15, have alerted Perth's responsible agencies to the implications that unplanned urban growth poses the ecosystem services' provision and ecosystem resilience [34]. However, there has been little or no awareness of the value that is being lost by neglecting stormwater sumps as opportunities for multifunctional urban green infrastructure and urban habitat.

1.3. The Sumps—An Overview

Although most of Perth's sumps are typically under a maintenance program (usually by local governments), many of them remain an eye-sore to the public and create significant wasteland, attracting weeds and litter. Local governments can be reluctant to upgrade the sumps to public green spaces due to their inability to ensure the stormwater function is maintained and the resulting perception that these sumps are for engineering purposes rather than local biodiversity and livability [35]. This paper tries to help resolve this perception by showing that they can be both.

In order to enable a local sump to be upgraded for biodiversity and livability functions, there is a need for system modification that can enable water infiltration to rapidly occur during large storms. The typical sump in Figure 1 needs to be upgraded first by ensuring it has sufficient capacity to handle stormwater. Figure 2 shows what was done in the WGV sump, but such system modifications depend on the specific hydrological capacity of a particular sump.

Figure 2. Drainage cells being installed at WGV to ensure adequate drainage function are maintained prior to landscaping. Credit: DevelopmentWA.

2. Materials and Methods

The case study methodology of qualitative inquiry [36] was used to define an emerging framework for mainstreaming; it aims to pursue how the actors, drivers, constraints, strategies, and values motivating stakeholders could reinvent the stormwater basins.

This paper is based on primary and secondary data, collected using a number of techniques and approaches developed by Francis [37] for landscape architecture case study research. It is based on document analysis (reports, audio-visual recordings, drawings), site visits, photographic documentation, an interview with a project leader, and the first-hand report from a co-author involved in the design of both projects. Using the principles and theories of biophilic urbanism and regenerative design, the article uncovers the designs

behind these successful biophilic initiatives and their ability to bring nature into modernist urban engineering.

The rationale behind this research methodology was that explanatory case studies can be used to develop a strategic approach to mainstreaming the regeneration of the sumps within the Perth stormwater system. Both cases presented certain conditions, factors, and processes that can provide a more in-depth understanding of the issues affecting a broader intake of biophilic urbanism.

The case studies involved diverse factors in the development of their projects, comprising social, environmental, and technological aspects in the strategies that oriented their processes. However, the effectiveness of the strategies implemented in both case studies, the WGV sump park and the Green Swing sump garden, needed to be assessed to consider mainstreaming possibilities that could arise from their work, integrating concepts of regenerative and biophilic design into urban planning and design.

The diagram in Figure 3 presents the analytical framework components:

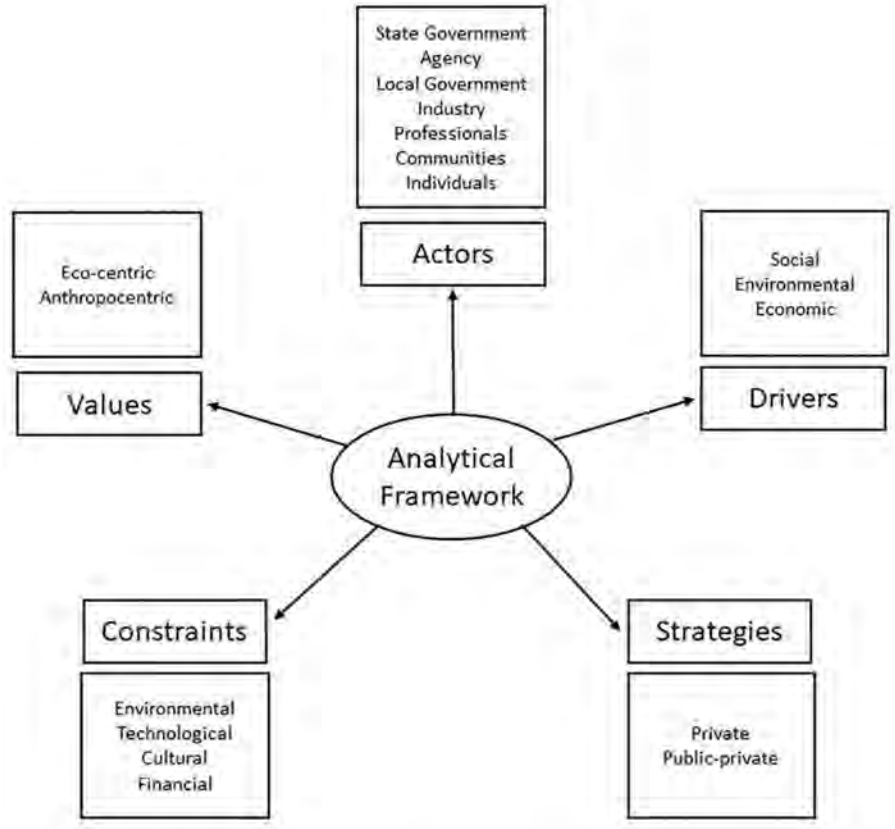


Figure 3. Analytical framework using qualitative inquiry. Credit: Authors.

The results for each case study will be presented first to show their ability to reach both stormwater goals and biodiversity/livability goals at the same time, then they will be analyzed to see how they could be mainstreamed.

2.1. Actors

Actors refer to the stakeholders, or all parties involved in the development of ideas, design, development, and implementation of a social-ecological project, in this case. Actors may be individuals, communities, institutions, local, state of federal governments, government agencies, professionals and consultants, industries, and other parties participating in the project [38,39].

2.2. Drivers

Social, economic, and environmental tenets are drivers supporting the strategies and actions behind the case studies, according to their scale, budget, and scope of intervention. In this context, biophilic urbanism and regenerative design are social-ecological tenets that are part of the concept of regenerative sustainability [29]. The built environment is seen as feasible to be restored and regenerated through the implementation of ecological design and engineering practices that are drivers in this project [16,28,29].

Social drivers involve the need to reconnect humans and nature through encouraging and facilitating human relational approaches between humans and other living organisms in urban settings, in this case. Regarding design application, this can be implemented in three main ways: (a) literal connection through direct relation to natural features, such as outdoors spaces, use of natural materials, vegetation, and water; (b) facsimile connection, by using nature imagery in forms, shapes, and materials; and (c) evocative connections using qualities and attributes of nature in design [5,7,21].

Economic drivers entail short- and long-term cost-benefit aspects, according to the complexity of needs and resources, budgetary availability, stakeholders' interests, and benefits expected from the mainstreaming of biophilic regeneration of sumps at neighborhood and future city scales. Another way for economic drivers to be considered is through the value uplift of property shown to be associated with biophilic urbanism, which brings economic value to a whole region of the city [40].

Environmental drivers relate to the restoration and re-establishing of the capacity of living systems to regenerate themselves, e.g., the restoration of damaged ecosystem services. Humans play a significant role in regenerating the healthy conditions of an ecosystem by creating an integral interconnection that promotes a mutually beneficial relationship between cities and their bioregions [16,23,26]. There are multiple other ways that local biophilic urbanism, such as the sumps, which are examined in this paper, contribute to urban improvements: greening public spaces, increasing local biodiversity, improving circular economy outcomes, and reduction of the urban heat island effect.

2.3. Strategies

Social-ecological approaches to the built environment promote design and development strategies to enable actions aiming to restore and enhance existing and potential conditions of a place, in both its biophysical and cultural aspects. Human activities have to be planned in a way that provides for and are provided by the systems where they take place by aligning human communities and economic activities with a place's capacity to support life [16,26].

This perspective implies a new role for designers and a design process that reflects the understanding of how life support systems and their subsystems work in the sites where interventions will take place [15]. This includes psychological and cultural literacy [16,26].

2.4. Constraints

In-depth knowledge of a place is crucial to the effective design and implementation process of regenerative biophilic interventions and their mainstreaming. Stakeholders need to consider hindrances and obstacles that may occur related to physical, environmental, institutional, technological, cultural, and other aspects [39].

2.5. Values

Values are understood as a set of beliefs, qualities, or behaviors that frame our goals and attitudes, providing standards against which individual or societal behaviors can be benchmarked. Hes and du Plessis [31] identified 10 appropriate values based on how nature works to ensure the healthy and continued functioning of the whole system, founded on the idea of an interconnected, interdependent, and integrated world. According to the focus or the main beneficiaries of a project's goals and actions, the approaches utilized may

be anthropocentric when the focus are human beings or eco-centric when all forms of life are the target.

Anthropocentric and eco-centric values can be balanced by implementing the strategies of biophilic and regenerative design into urban environments. Biophilic design tends to seek human health and wellbeing, while regenerative design principles tend to look at creating conditions for all living systems [26,29].

3. Case Studies

3.1. WGV Sump Park

Situated in the City of Fremantle's local government area, the WGV residential development was described as 'a carbon positive living laboratory', as it was designed to demonstrate an innovative approach—"Innovation Through Demonstration"—to urban infill, which included all the One Planet Living goals and, in particular, the goal to achieve zero carbon outcomes [41,42]. This approach aimed to introduce higher densities, diversity of housing types and sizes, responding to changing demographic cohorts and climate conditions, including an award-winning social housing initiative called Sustainable Housing for Artists and Creatives (SHAC), amenities, and a range of sustainability initiatives, such as energy, water, and landscaping strategies. This new residential estate, comprising more than 80 residential units, was developed on a 2.29-hectare former school site, owned by the Western Australian State Government, by DevelopmentWA (the WA state government land development agency). Adjacent to this area was a fenced sump owned and managed by the local government. The sump was integrated into the development's planning [31,43,44] and became, what is called in this paper, the WGV sump park.

The City of Fremantle and DevelopmentWA were the key supporters of the project. Together with Curtin University, the community of White Gum Valley, private sector investors, engineering, and environmental design consultants were involved in generating sustainable solutions to increase the quality of life, address the environmental and social challenges, and create a sustainable community [31,42]. To help achieve these objectives, the One Planet Living framework was used [41].

The structure plan for the WGV development subdivided the area into 28 development lots and open public spaces. The revitalization of the adjacent 0.16-hectare sump aimed to convert the underutilized space into a publicly accessible landscape, which would add social, economic, and environmental value to the residential estate while still performing its function as a drainage overflow area with a capacity of 2000 cubic meters. The revitalization project encompassed engineering and earthworks to deal with stormwater effectively and a landscape design to ensure that local biodiversity and canopy increase and provide recreational green space to the community [31,45].

On the engineering side, the project team conducted an assessment of the sump capacity and modelled the expected performance. The results indicated that the existing conditions at the time (2015) complied with the 5-year ARI (average recurrence interval) event but not with the 100-year ARI event. Considering the landscape project to be developed on site, a consultant's recommendation was to install water storage cells underground to maximize the stormwater storage, a simple and effective sustainable urban drainage approach to manage stormwater on-site [46]. To protect the drainage system, urban stormwater debris from the surrounding catchment is captured by gross pollutant traps, which are cleared out regularly [45].

The design incorporated water-sensitive urban design principles and water efficiency measures. The landscape concept was based on a winter wet depression feature, where plants that prefer seasonally wet conditions occur at the bottom of the sump and those that prefer drier conditions grow at the top. The plant palette included a diverse range of trees, shrubs, grasses, and groundcovers that are native to the area for biodiversity benefits. Large boulders of locally occurring limestone were chosen for retaining the embankment of the sump in an informal way [45]. The result of this landscaped public space was expected to strongly contribute to creating sense of place, health, and wellbeing for users and residents

(Figure 4) and was formally assessed by the Fremantle Council after close discussions with the local community, who also agreed to help with providing local history narratives that could be used in the park.

Figure 4. WGV sump park landscape plan. (Key: 1. Informal nature play with climbing logs; 2. Pathways made from crushed recycled rubble; 3. Gross pollutant traps; 4, 9, & 10. Bubble-up pits from underground cells; 5. Air-vent for underground cells; 6. Limestone boulders; 7. Log seats; 8. Planted street verge; 11. Steps.) Credit: JBA.

The sump regeneration project achieved notable results. The multiple outcomes of the site have been documented [42] to show that it met many targets. In terms of hydraulic performance, the sump successfully manages stormwater events. Residents and passersby enjoy the new park, and the vegetation is establishing well (Figures 1 and 5).

In terms of the One Planet Living principles that used to inform the design of WGV, the sump park supports the "Land use and wildlife" principle through creating new habitats and contributing to an increase in biodiversity. It also addresses "Sustainable water" through reduction of flood risks and reducing potable water use, as well as "Sustainable materials" and "Zero waste" [41,44]. The livability elements of the WGV sump park are less defined in goals and outcomes, but it is clearly popular, with many public events being held in the space. It is an innovative communal green space, featuring local heritage stories and public space infrastructure, which is now a major part of a local community.

3.2. Green Swing Sump Garden

The Green Swing is the name of the group of "citizen developers" who collaboratively developed an innovative residential cluster called Genesis in Lathlain, Victoria Park. The group initiated the project in 2009 as a sustainable living venture by purchasing an 840 m^2 lot, located 5 km from Perth CBD, close to a train station and adjacent to a fenced stormwater sump (Figure 6). The project resulted in the construction of two townhouses and two apartments on the one block. The buildings were designed to be solar passive for thermal comfort and incorporated renewable energy systems, rainwater harvesting, and greywater reuse. An energy monitoring system was installed to monitor energy usage [47,48].

The decision to develop on the site at 96 Rutland Avenue was influenced by the proximity to the sump, which is one of the 130 such sumps owned and managed by the Town of Victoria Park as the local government authority [49]. The group proposed to transform the underutilized space around the sump into a productive and recreational space, and to that purpose received advice from a design consultant for the early stages of the planning process.

Figure 5. The WGV sump park shortly after completion being used by the public for educational purposes. Credit: JBA.

The majority of the implementation and management of the sump garden was driven by the proponents, in collaboration with a local community garden association, with the aim of setting a precedent that could become a model of biophilic regeneration of underutilized urban green assets in Victoria Park and beyond to other parts of Perth.

A landscaping plan for the 175 m^2 site prepared for the sump by the design consultant included revegetation with plant species, as well as some fruit-bearing plants. The plan featured footpaths, garden furniture, and space for community gardening. The lowest part was retained for stormwater infiltration. No additional engineering or earthworks were undertaken because the sump was adequately sized (Figure 7) and unaltered in its function by any of the other landscaping. Its capacity is much smaller than the WGV sump park and was considered more than sufficient to meet the stormwater infiltration requirements.

The sump next to the development site in Lathlain before revitalisation. Source: JBA

The Green Swing sump garden with trees and understory species planted by members of the local community. Source: JBA

Figure 6. The sump in Lathlain before and after revitalization. Credit: JBA.

Figure 7. Green Swing sump garden landscape plan. (Key: 1. Vehicle access pathway to council requirements; 2. Native verge plantings; 3. Access gate; 4. New fence alignment; 5. Food forest; 6. Original fence alignment; 7. Pedestrian paths; 8. Controlled access and sight lines from adjacent property; 9. and 11. Stormwater outlets; 10. Base of sump; 12. Native grasses and groundcovers to stabilize sump banks; 13. Layered native shrubs and trees for habitat.) Credit: JBA.

The proposal to convert the sump into a community garden was submitted to the Town of Victoria Park and was endorsed by the council. The Green Swing sump garden became the first satellite community garden for the Victoria Park Community Garden Association, who agreed to manage it. The proponents also anticipated that the innovative sump project would become an inspiration for others to undertake a similar challenge.

The project was privately funded by the proponents, and all the landscaping work was performed by the residents of Genesis, who also purchased and planted the seedlings [48].

The sump garden upholds its original function as a stormwater basin. The conversion of this formerly underutilized area into a community garden incorporated native plant species, fruit trees, and vegetable garden beds, bee keeping, and chickens (Figures 7 and 8). According to the residents, the Town of Victoria Park was very supportive since the beginning of the project, and every 6 months, they carry out inspections in the sump gardens [47]. So far, the governance approach afforded by the local Victoria Park Community Garden Association has been successful.

Figure 8. The sump garden is used for a range of urban agriculture activities, including bee keeping. Credit: Rob Frith.

The sump garden is a productive green space and a place of relaxation for the residents of the Genesis and the local community. As the project leaders explained, 'the Green Swing was about the journey towards a more sustainable community, getting to know your neighbors and looking after the environment we live in' [47,48].

4. Comparative Analysis Using the Framework for Mainstreaming

The results from applying the framework to the case study analysis are presented in Table 1. The analysis sets out commonalities and disparities between both cases, WGV and the Green Swing. The following aspects and elements of the projects have been compared: project's size, time of design and construction, scope and scale, actors involved, drivers that motivated actions, available budgets, strategies and processes used, constraints, and values. Through this comparative analysis, the authors attempt to see if the regeneration of old modernist sumps into regenerative biophilic urban assets can contribute to creating sustainable communities and inform policies for replication in other locations looking for healthy communities and ecosystems to thrive together.

Both cases were created and constructed in the same decade of the 2010s. But they differ in scale and scope; while the Green Swing involves four residential units, besides the sump garden, the WGV is a residential precinct development that comprises more than 80 units, amenities, and green open space. Due to the differences in scale and scope, they present a diversity of actors involved. The Green Swing vision was conceived by a small group of citizen developers, who attracted others with a similar mindset and interests. The WGV vision originated from conversations among the local government, state agencies, and local community about the need to innovate residential precincts' design [43]. This suggests that small to medium local biophilic regeneration projects can be initiated and led by community members and may only require minor input from professional consultants if technological involvements are not requested. Both cases have been designed and

developed as innovative responses to sustainable urban living expectations, boosted by social, environmental, and economic drivers. It is interesting to note that many social and environmental drivers overlap.

Table 1. Comparative analysis of the WGV Sump Park and the Green Swing Sump Garden. Credit: Authors.

	Green Swing	**WGV**
Actors	Group of owner-builders and individuals with common interests and values Professional consultant	Community Professional consultants (engineering, environmental, and landscape design) Local Government: City of Fremantle State Government Agencies: DevelopmentWA
Drivers	Social (building a sustainable community; creating space for community collaboration and enjoyment; providing inspiration for the wider community; beautification of the area surrounding the development) Economic (self-funded; uplift property value) Environmental (increase urban green space; contribute to local biodiversity)	Social (demonstrate "Innovation through Demonstration" model; enhance attractiveness of the area surrounding the development) Economic (alignment of key stakeholders' interests; budget availability; uplift property value) Environmental (increase of urban green space; biodiversity enhancement; addressing canopy loss)
Strategies	Private initiative Developing an innovative approach to increase urban green space through the creative use of the underutilized space of the adjacent sump.	Public-private partnership Creating "Innovation by Demonstration" model One Planet Living framework Water-sensitive urban design
Constraints	Model development Concerns at community level Concerns at local government level, mainly health and safety issues Obtaining permissions and approvals Lack of clear policy guidelines	Concerns at government level-flood modeling issues, health, and safety issues Obtaining permissions and approvals

The drivers highlighted by the stakeholders of the Green Swing sump garden focus mainly on social and environmental benefits, for example, inspiring the local community to engage in the process of enhancing the urban landscape, as well as building connections between the individuals (members of the community). The sump garden provided a place for collaboration, such as food production and enjoyment of the natural space, helping to build community. For the stakeholders of the WGV sump park project, one of the main objectives was demonstrating how to effectively utilize space in a medium-density development to deliver ecological, social, and economic benefits. Hence, the sump park was highly dependent on local government and state agencies for financial support, as well as engineering and environmental technical advice and development. The sump park focus was directed towards mitigation of canopy loss and biodiversity enhancement. For all the stakeholders, the environmental issues were crucial to address.

Strategies used responded to the objectives and scale of each project. The Green Swing sump garden was a small-scale project supported by a simple and clear strategy that regarded the sump biophilic regeneration as an opportunity to increase urban green space and gain additional productive and recreational space for community building while inspiring other communities to do the same. It proceeded because the local authorities could support it without needing to increase its budget to accommodate its management. The involvement of a local gardening group was a critical step in this process. The WGV sump park was a more complex and larger-scale project that needed a stronger professional strategy. A public-private partnership was then developed that created an "Innovation through Demonstration" model and utilized the One Planet Living sustainability framework and the guidelines of water-sensitive urban design to steer their actions. Thus, strategies were

to involve volunteers for the small scale and professional advice for the large-scale. Both were appropriate in creating the necessary support to deliver the projects.

In regard to the constraints affecting the progress of the projects, similar issues emerged for both cases, for example, concerns at the local government level, which had to be addressed in order to obtain relevant approvals. Health and safety issues became a priority for local governments and communities; in both cases, removing the fence and allowing public access was the main health and safety concern. In the case of the Green Swing sump garden, the local government decided to keep the existing fence, though it had an easily opened gate. To retrofit the WGV sump, a hydrological assessment was undertaken to determine the required sump capacity and the potential to use underground drainage cells and landscaping to meet drainage and social requirements. It was a costly process that could only be achieved with financial support from the City of Fremantle and DevelopmentWA. A business case for the Green Swing sump garden was deliberately avoided as it was considered another obstacle by the project proponents [48], and this confirms the importance of having a project small enough to be seen as primarily a volunteer exercise.

The challenges identified as the most difficult to overcome were related to legal status, path dependency, and leadership. Other common difficulties and obstacles during different stages of the project included obtaining relevant permissions to develop the sumps and reassuring the skeptical officers in government agencies about the feasibility of the projects. The approval of the drainage cells proposed for the WGV sump park was described as a lengthy process. Similar opinions came from the citizen developers of the Green Swing, which listed lengthy approval processes as one of the main obstacles.

The values supporting the actions show similarities related to social, ecological, and economic aspects and reflect the initial objectives related to livability and biodiversity. In both cases, the personal values of those involved were clear as they praised community building, innovation, sustainable urban living, and place-making, as well as sustainable food production (in the Green Swing case). In both cases, place-making manifested as a strong value to provide facilities for the local community to interact and develop ownership of the place. The principles of sustainable development highlighted in the One Planet Living program became the source of professional values that the stakeholders at the WGV would share and follow. The values required to develop place-based water-sensitive landscape design showcase conservation efforts, environmental regeneration, and biodiversity enhancement. For the developers of the Green Swing sump garden, the values oscillated around community building and sustainable urban farming. The modest design and volunteer-based governance were aimed at expressing these values and enabling the local community to be able to create the on-going maintenance of the areas as they came to live there with their families.

Environmental values were strongly indicated, especially biodiversity, ecological regeneration and conservation, and water management (in the WGV case). These values were not seen as harming the economic prospects for their developments, in particular, there was an expectation that they would uplift the property value. In the case of WGV, the precinct won a number of significant awards and the sales of the lots and units were generally more rapid than the market at that time. The sump park was also seen to provide social and educational value to the wider community of White Gum Valley. The Green Swing park was considered to have contributed to the area's improved real estate value.

Both cases aimed at demonstrating innovative approaches to increase urban green space. The old stormwater sumps became multifunctional features, serving not only as stormwater infrastructure but also enhancing recreational and educational infrastructure and biodiversity. Enhancing attractiveness and overall beautification of the developments and the adjacent surroundings became one of the leading drivers for both communities and developers. The educational, recreational, and ecological aspects of the regeneration projects appear to fulfil the objectives of biophilic urbanism and regenerative design.

The framework suggests strong reasons for mainstreaming biophilic revitalization of stormwater infrastructure at both a small and large scale.

5. Conclusions

The paper has reviewed the biophilic regeneration of two stormwater sumps in Metropolitan Perth, and the results have indicated that multiple outcomes favoring biodiversity regeneration and local community benefits can be achieved whilst enabling effective stormwater management. From the perspective of the biophilic urbanism agenda, this is a more favorable design outcome than the outcome obtained from the 1940s style of modernist engineering.

The question posed in this paper asked how such a design can be mainstreamed and whether the two sumps could shed light on whether this is possible.

Regenerating stormwater infiltration basins have drivers, dynamics, and values that can enable sustainable outcomes. The analysis of the two case studies in Metropolitan Perth reveals that the barriers to the wider implementation of the biophilic approach to the sumps' revitalization and repurposing are mainly socio-institutional but can be overcome at both small-scale and big-scale sumps.

The Green Swing sump garden is a successful design for a small-scale sump, which demonstrates how a creative use of underutilized areas can contribute to sustainable urban living and serves as a model to be adapted to other places and communities. Similarly, the WGV sump park has shown the multiple benefits for a whole community or suburb by regenerating a large-scale stormwater sump.

The results of the comparative analysis suggest that the key difference between the small- and large-scale projects is in their governance approach to delivering and maintaining the sumps. The small scale was largely a volunteer approach in delivery and maintenance, and the large scale was a fully professional approach, involving greater commitment from an on-going maintenance budget from the local government authority. The local small-scale regeneration project suggests that such small systems can be initiated and successfully led to completion by a group of charismatic community members with necessary but limited input from other professionals. The large-scale regeneration project can similarly work but requires more partnerships to be developed and a fully professional assessment process. In both cases, leadership was needed to drive the necessary changes, though this may be enough to enable the policies and strategies to be mainstreamed, as the demonstrations have shown multiple benefits with few, if any, negative side effects.

The two projects analyzed here suggest that it is necessary to develop such inspirational examples to create the kind of mainstreaming necessary for biophilic urban regeneration in general and that the two-scale approach may have benefits in many other kinds of biophilic and regenerative urbanism. Another lesson that emerged from the analysis of the results is that health and safety issues need to be addressed at the proposal stage to secure adequate approvals from local authorities. In the case of the Perth sumps, alternative health and safety design solutions need to be tested and, if successful, they need to be made publicly available in order to encourage similar regenerative projects.

These projects have helped educate communities, property owners, local councils, utilities, and developers, showing that quality green urban assets should not be viewed as "optional extras" in any urban development but as critical elements of successful, value-driven, economic developments at a small and large scale.

Author Contributions: Conceptualization, A.C., M.E.Z.d.B. and P.N.; investigation, A.C. and J.B.; methodology, A.C. and M.E.Z.d.B.; supervision, P.N.; writing—original draft, A.C. and M.E.Z.d.B.; writing—review and editing, A.C., M.E.Z.d.B., P.N. and J.B. Unless otherwise noted, all photographs were by the authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by the CRC in Low Carbon Living, grant number NP2002.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Human Research Committee of CURTIN UNIVERSITY (Approval Number HRE2016-0258, date of approval 31 August 2016).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data sharing not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IPCC. Summary for Policymakers. In *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*; Masson-Delmotte, V., Zhai, P., Portner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., et al., Eds.; World Meteorological Organization: Geneva, Switzerland, 2019; Available online: https://www.ipcc.ch/site/assets/uploads/2018/10/SR15_SPM_version_stand_alone_LR.pdf (accessed on 17 November 2020).
2. The Nature Conservancy. Nature in the Urban Century. A Global Assessment of Where and How to Conserve Nature for Biodiversity and Human Wellbeing. Available online: https://www.nature.org/en-us/what-we-do/our-insights/perspectives/nature-in-the-urban-century/?vu=r.d_urbannature100 (accessed on 17 November 2020).
3. Söderlund, J. The Emergence of a New Social Movement: Biophilic Design. In *The Emergence of Biophilic Design*; Springer Nature: Cham, Switzerland, 2019; pp. 1–11.
4. Lin, B.B.; Meyers, J.; Beaty, R.M.; Barnett, G.B. Urban green infrastructure impacts on climate regulation services in Sydney, Australia. *Sustainability* **2016**, *8*, 788. [CrossRef]
5. Beatley, T. *Biophilic Cities: Integrating Nature into Urban Design and Planning*; Island Press: Washington, DC, USA, 2011.
6. Beatley, T. *Handbook of Biophilic City Planning and Design*; Island Press: Washington, DC, USA, 2016.
7. Kellert, S.; Heerwagen, J.; Mador, M. (Eds.) *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*; John Wiley & Sons: Hoboken, NJ, USA, 2008.
8. Newman, P. Biophilic urbanism: A case study on Singapore. *Aust. Plan* **2014**, *51*, 47–65. [CrossRef]
9. Newman, P. Infrastructure Planning. In *Planning Boomtown and Beyond*; Biermann, S., Olaru, D., Paul, V., Eds.; UWA Publishing: Perth, Australia, 2016; Available online: https://research-repository.uwa.edu.au/en/publications/planning-boomtown-and-beyond (accessed on 12 November 2020).
10. Raja Segaran, R.; Lewis, M.; Ostendorf, B. Stormwater quality improvement potential of an urbanised catchment using water sensitive retrofits into public parks. *Urban For. Urban Green.* **2014**, *13*, 315–324. [CrossRef]
11. Grose, M.J.; Hedgcock, D. Designs for Stormwater Disposal in Public Open Space: An Ecological Assessment of Current Practices in Western Australia. In Proceedings of the 1st Australian National Hydropolis Conference, Perth, Australia, 8–11 October 2006; Available online: http://www.hydropolis.com.au/papers.htm (accessed on 12 November 2020).
12. Department of Water and Environmental Regulations. *Stormwater Management Manual for Western Australia*; Department of Water and Environmental Regulations: Perth, Australia, 2007; Available online: https://www.water.wa.gov.au/urban-water/urban-development/stormwater/stormwater-management-manual (accessed on 17 November 2020).
13. Cooper, W.S. Drainage and Irrigation. In *Western Landscapes*; Gentilli, J., Ed.; University of Western Australia Press: Nedlands, Australia, 1979.
14. Söderlund, J. *The Emergence of Biophilic Cities*, 1st ed.; Springer International Publishing: London, UK, 2019.
15. Lyle, J.T. *Regenerative Design for Sustainable Development*; John Wiley & Sons, Inc.: New York, NY, USA, 1994.
16. Reed, B. Shifting from "sustainability" to regeneration. *Build. Res. Inf.* **2007**, *35*, 674–680. [CrossRef]
17. Melk, A. Documentary—The Regenerates. Australia. 2015. Available online: https://vimeo.com/120837455 (accessed on 17 November 2020).
18. Benne, B.; Mang, P. Working regenerative across scales–insights from nature applied to the built environment. *J. Clean Prod.* **2015**, *109*, 42–52. [CrossRef]
19. Fink, H. Human-nature for climate action: Nature-based solutions for urban sustainability. *Sustaiability* **2016**, *8*, 254. [CrossRef]
20. Cabral, I.; Costa, S.; Ulrike Weiland, U.; Bonn, A. Urban Gardens as Multifunctional Nature-Based Solutions for Societal Goals in a Changing Climate. In *Nature-Based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions*; Kabisch, N., Korn, H., Stadler, J., Bonn, A., Eds.; Springer: Cham, Switzerland, 2017; pp. 237–253.
21. Keller, S.; Calabrese, E. The Practice of Biophilic Design. 2015. Available online: www.biophilic-design.com (accessed on 17 September 2019).
22. Salingaros, N.A. Life and the Geometry of the Environment. *Athens Dialogues E J. Harv. Univ. Cent. Hell. Stud.* **2010**, *2*, 1–19. Available online: http://permaculture.org.au/2010/10/14/life-and-the-geometry-of-the-environment/ (accessed on 17 November 2020).
23. Zingoni de Baro, M.E. Towards Regenerative Sustainable Urbanism: The case of Curitiba and Singapore. *Ph.D. Thesis*; Curtin University: Perth, Australia, 2015. Available online: https://espace.curtin.edu.au/bitstream/20.500.11937/56444/1/ZingonideBaro2015.pdf (accessed on 18 November 2020).

24. Panagopoulos, T.; Sbarcea, M.; Herman, K. A biophilic mind-set for a restorative built environment. *Landsc. Archit. Art* **2020**, 17. [CrossRef]
25. Loures, L.; Crawford, P. Democracy in progress: Using public participation in post-industrial landscape (re)-development. *WSEAS Trans. Environ. Dev.* **2008**, *9*, 794–803.
26. Mang, P.; Reed, B. Designing from place: A regenerative framework and methodology. *Build Res Inf.* **2012**, *40*, 23–38. [CrossRef]
27. Mang, P.; Reed, B. Regenerative Development and Design. In *Sustainable Built Environments*; Encyclopedia of Sustainability Science and Technology Series; Loftness, V., Dagmar, H., Eds.; Springer: New York, NY, USA, 2020; pp. 478–501.
28. Du Plessis, C. Towards a regenerative paradigm for the built environment. *Build. Res. Inf.* **2012**, *40*, 7–22. [CrossRef]
29. Hes, D.; Du Plessis, C. *Designing for Hope: Pathways to Regenerative Sustainability*; Routledge: Abingdon, UK, 2015.
30. Hopper, S.D.; Gioia, P. The Southwest Australian floristic region: Evolution and conservation of a global hot spot of biodiversity. *Annu. Rev. Ecol. Evol. Syst.* **2004**, *35*, 623–650. [CrossRef]
31. Byrne, J.; Green, M.; Dallas, S. WSUD Implementation in a Precinct Residential Development: Perth Case Study. In *Approaches to Water Sensitive Urban Design*, 1st ed.; Sharma, A.K., Gardner, T., Begbie, D., Eds.; Elsevier: Amsterdam, The Netherlands, 2018; Available online: https://www.elsevier.com/books/approaches-to-water-sensitive-urban-design/sharma/978-0-12-812843-5 (accessed on 17 November 2020).
32. Newman, P. The Rise of a sustainable City. *Griffith Rev.* **2015**, *47*, 131–160. Available online: https://espace.curtin.edu.au/handle/20.500.11937/26587 (accessed on 17 November 2020).
33. Seddon, G. *Sense of Place. A Response to an Environment, the Swan Coastal Plain, Western Australia*; University of Western Australia Press: Perth, Australia, 1972.
34. Weller, R.; Drozdz, Z.; Kjaersgaard, S.P. Hotspot cities: Identifying peri-urban conflict zones. *J. Landsc. Archit.* **2019**, *4*, 8–19. [CrossRef]
35. City of Melville. *Public Spaces Strategy*; City of Melville: Melville, Australia, 2017; Available online: https://www.melvillecity.com.au/our-city/publications-and-forms/urban-planning/city-of-melville-public-spaces-strategy (accessed on 10 September 2020).
36. Yin, R.K. *Case Study Research: Design and Methods*, 4th ed.; SAGE Publications: Thousand Oaks, CA, USA, 2009.
37. Francis, M. *A Case Study Method for Landscape Architecture: Final Report to the Landscape*; Landscape Architecture Foundation: Washington, DC, USA, 1999; Available online: https://www.lafoundation.org/sites/default/files/2019-01/casestudymethod.pdf (accessed on 17 November 2020).
38. Burandt, S.; Gralla, F.; John, B. Actor Analysis in Case Studies for (regional) Sustainable Development. *Envigogika* **2015**, *10*, 1–14. [CrossRef]
39. Ferreira, V.; Barreira, A.; Loures, L.; Antunes, D.; Panagopoulos, T. Stakeholders' Engagement on Nature-Based Solutions: A Systematic Literature Review. *Sustainability* **2020**, *12*, 640. [CrossRef]
40. Cabanek, A.; Newman, P. Biophilic urban regeneration: Can biophilics be a land value capture mechanism? In *Sustainable Development and Planning VII*; Brebbia, C.A., Zubir, S.S., Hassan, A.S., Eds.; WIT Press: Southampton, UK, 2016; pp. 65–74. Available online: http://library.witpress.com/viewpaper.asp?pcode=SDP16-006-1 (accessed on 17 November 2020).
41. Bioregional. *WGV by Landcorp—One Planet Action Plan*; Bioregional: London, UK, 2015; Available online: https://www.bioregional.com/projects-and-services/case-studies/wgv-at-white-gum-valley-innovation-in-sustainable-and-affordable-self-build-homes (accessed on 19 November 2020).
42. Wiktorowicz, J.; Babaeff, T.; Breadsell, J.; Byrne, J.; Eggleston, J.; Newman, P. WGV: An Australian urban precinct case study to demonstrate the 1.5 °C agenda including multiple SDGs. *Urban Plan* **2018**, *3*, 64–81. Available online: https://www.cogitatiopress.com/urbanplanning/article/view/1245 (accessed on 17 November 2020). [CrossRef]
43. CRC for Water Sensitive Cities. White Gum Valley—A Waterwise Way of Living. Available online: https://watersensitivecities.org.au/solutions/case-studies/white-gum-valley/ (accessed on 10 November 2020).
44. Landcorp. *One Planet Action Plan 2018 Review*; Landcorp: Perth, Australia, 2018; Available online: https://www.bioregional.com/resources/wgv-one-planet-annual-review-2018 (accessed on 17 November 2020).
45. Byrne, J. *A Different Approach—Gardening Australia*; Australian Broadcasting Corporation: Sydney, Australia, 2018; Available online: https://www.abc.net.au/gardening/factsheets/different-approach/9524974 (accessed on 19 November 2020).
46. Hyd2o. *Review of Existing Council Sump Capacity, White Gum Valley*; Hyd2o: Perth, Australia, 2015; Available online: http://www.hyd2o.com.au/ (accessed on 17 November 2020).
47. Byrne, J. *A Thriving Community—Gardening Australia*; Australia Broadcasting Corporation: Sydney, Australia, 2017; Available online: https://www.abc.net.au/gardening/factsheets/a-thriving-community/9439672 (accessed on 19 November 2020).
48. Stockmann, E.; (Co-operation Housing, Perth, Australia). Personal communication, 26 June 2018.
49. Landgate. Town of Victoria Park Online Maps. Available online: http://maps.victoriapark.wa.gov.au/intramaps96/default.htm?project=VictoriaPark (accessed on 19 November 2020).

Appendix G: Publication 5

Publication 5

Cabanek, A., Newman, P. & Nannup N. (2021). Indigenous Landscaping and Biophilic Urbanism: Case Studies in Noongar Six Seasons. *Submitted to Sustainable Earth*

Indigenous Landscaping and Biophilic Urbanism: Case Studies in Noongar Six Seasons

By Agata Cabanek[a], Peter Newman[a] and Noel Nannup[b].

[a] CUSP, Curtin University; [b] Noongar Elder

Abstract

Indigenous landscaping has had a revival with Indigenous cultures as an important part of multiculturalism. The landscape elements are generally gleaned from Indigenous Elders and from anthropological texts and pre-invasion history texts (e.g. explorers' notebooks) that enable an understanding of the ecological, food and medicine aspects of their propagation. This paper will examine how Indigenous landscaping (knowledge, values, management methods, use) can assist with biophilic urbanism, the new approach to bringing natural systems into the built environment. This emphasises the importance of place meanings in biophilic design. It will illustrate this in Western Australia using the Noongar People's six seasons of distinct landscape each with importance for providing a living environment (shelter, food, medicine and spiritual nourishment) and as a basic requirement for biodiversity management over 60,000 years. Three stages in awareness of the value in these six seasons are outlined: early setting areas aside; regenerating cleared public areas; and landscaping the whole city. Case studies in Six Seasons Gardens are used to show how bringing a cultural element into landscaping can bring many advantages.

1. Introduction

In 2015, along with 192 other countries, Australia adopted the 2030 Agenda featuring seventeen Sustainable Development Goals (United Nations, 2015). Some of the goals concern the natural environment and urban living, for example, Goal 11 Sustainable Cities and Communities and Goal 15 Life on Land. The main objectives of these are to "make cities and human settlements inclusive, safe, resilient and sustainable" and to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (Australian Government, 2015).

Recently, the Global Biodiversity Outlook 5 report revealed that countries worldwide failed to meet even a single biodiversity target set for 2020 (Secretariat of the Convention on Biological Diversity, 2020), which means that an estimated one million species of flora and fauna still face extinction.

This paper will set out a new approach to biodiversity management that will attempt to show how cities can play a bigger role. It will in particular try and show that the rapid growth in the indigenous landscaping movement will need to see cities as their next major focus. It will illustrate this by examining an emerging overlap between indigenous landscaping and biophilic urbanism in Australian cities with application to many cities across the planet.

Australia is one of the most biodiverse places on earth (Chapman, 2009) but has so far had limited success in preventing this being lost. Preventing the loss of species in the past has focussed on strategic planning for conservation and rehabilitation of the land systems across the countryside but increasingly there have been calls for new approaches to making urbanised areas more sensitive to their biodiversity inside and around their built forms (Connop & Nash, 2018; Hes & Du Plessis, 2015). A research study by Ives (2016) suggested that Australian cities present opportunities for national biodiversity conservation. This paper examines how biophilic urbanism, a new approach to biodiversity in cities, can also integrate with the broader goal of how to be inclusive with indigenous values and communities. It examines how this is working out in Perth, Western Australia where the oldest living culture is beginning to be drawn into how their landscape knowledge can help to make better cities and how this can lead to more hopeful biodiversity gains.

2. Biophilic urbanism and biophilic design

Biophilic urbanism is based on the knowledge that humans have an innate connection with nature that should be maintained on a daily basis (Kellert, 2016). The main biophilic design features enable nature to become an integrated part of roofs, walls, balconies, indoor landscaping and implementation of nature-based solutions between buildings (such as green infrastructure) (Cabanek, Zingoni de Baro, Newman, 2020). A major driver in how biophilic urbanism works is the way that biophilic responses create human health outcomes through actual physiological mechanisms ((Alexandra & Norman, 2020; McDonald et al., 2018). Biophilic urbanism therefore fosters many urban resilience outcomes for better economies,

better community and better natural systems (Daniels et al., 2020). As a strategic approach to urban development, it can therefore assist with achieving the SDGs.

By implementing the biophilic urbanism agenda, cities should be able to assist with the enhancement of local biodiversity (Birkeland, 2015; Newman, 2014; SBEnrc, 2011) and meet other SDGs at the same time. Biophilic urbanism encompasses many types of ecological systems and human activities (Kellert, 2016) instead of focusing on a single building, urban spaces, and particular human activity, as landscape design often does. Kellert and Calabrese (2015) have identified principles for the effective practice of biophilic design which are compatible with the natural world:

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

The missing link is that biophilic design has not made much yet of the need to establish an Indigenous relationship to the culture and practices of Indigenous landscaping and how this can indeed improve biophilic urbanism and hence biodiversity as well as better cities.

3. Indigenous Landscaping

To build a nature-positive economy is a responsibility of all, and the recognition of the potential for indigenous knowledge to contribute to sustainable and regenerative development is seen to be a major new agenda. Indigenous people have a long history of deploying nature-based solutions, however, not many countries have recognised this knowledge as necessary in building a sustainable economy and sustainable living environments, especially in cities (WEF, 2020).

Since urban public places become more diverse and multicultural, a better understanding of how various populations use those places and what values are attached to them could help urban planners and designers to deploy adequate design tools and solutions. Low et al. (Low et al., 2005) argue that the most successful public spaces are those where the identities of different cultural groups are emphasized and celebrated so people of different cultural and ethnic backgrounds use the spaces without concern for being stigmatised and people learn to appreciate each other. Culturally appropriate public spaces are essential to the community's success (Knapp, 2008) and building a sense of place (Yazdani & Lozanovska, 2014). Vibrant neighbourhoods foster social interactions and have a greater level of social capital (Knapp, 2008; Low et al., 2005). It is, therefore, necessary for biophilic urbanism to address the needs of multicultural societies and provide urban places that could build social, economic and ecological capital.

Despite growing academic and practitioner research on biophilic design, there is some misunderstanding that solely introducing plants between and on buildings would trigger biophilic responses (Downton et al., 2017). However, human responses generally require some sense of meaning as well as an attractive environment. Kellert and Calabrese (2015) recognise that the expected responses from biophilic spaces can be achieved by considering many more environmental and human factors than solely the inclusion of plants. Diverse contextual, cultural and ecological needs are the factors that should be considered by the designers to trigger biophilic responses. As Lachowycz and Jones (2013) pointed out, the design must be appropriate to diverse human social and ecological needs. It means that the biophilic design solutions developed for one project should not be simply recreated in other places without consideration for the local cultures, traditions and ecological context. Similarly, the conclusions from one study may not be applicable in a different context and population.

Biophilic urbanism everywhere needs to consider *place* and its meanings to provide the deepest kind of responses that can intensify the experience of nature in cities. Thus in this paper we look at how Australia can facilitate the emerging integration of local indigenous ecological knowledge from aboriginal Australians with the emerging area of biophilic urbanism. The paper attempts to do that by examining the local landscape which is part of the ancient continent of Gondwana and how the Noongar culture in South Western Australia, that has a 60,000-year continuous history, in

recent times has begun to be understood and applied to how the region in and around Perth can be better managed (Hopper et al., 1997; Nannup, 2006).

4. Noongar Indigenous Landscaping

Considering that Indigenous Australians have been the custodians of the lands, waters and diverse fauna and flora for at least 60,000 years (Gammage, 2012; Pascoe, 2018) and continue to maintain a strong connection to the natural environment, it seems important for biophilic urbanism to have a greater insight into indigenous knowledge and environmental practices in such ancient cultures that continue into today's cities and regions. It is necessary to at least begin to seek collaboration with the traditional custodians of the lands in order to deliver adequate and culturally appropriate developmental strategies and achieve inclusive biophilic outcomes in urban environments. There is evidence that this has started but little evidence exists of how landscaping cities could use this knowledge.

Indigenous knowledge is based on spirituality which is based on their relationship with the natural world (Gammage, 2012). The native knowledge and spirituality are strongly tied to the natural environment and the landscapes across Australia with 32 different language groups, each with their own place for which they have had responsibility for many generations and now are in various stages of native title recognition. Indigenous spirituality emerges through the patterns and forms in natural landscapes and is reinforced by the traditional oral interpretations and song-line stories. The Indigenous artefacts and symbols reveal an alternate perception of the natural environment, and this adds another layer of meaning to particular urban localities (Jones et al., 2018; Tucker et al., 2018).

The Noongar nation has evidence of its past cultural activity going back 60,000 years and their presence in the land has begun to be recognised legally. The South West Native Title Settlement for Noongar people in Western Australia, aims to resolve native title claims in exchange for statutory recognition of the Noongar people as the traditional owners of south-Western Australia. It is the largest native title settlement in Australian history, affecting about 30,000 Noongar People and encompassing around 200,000 km^2 (77,000 sq mi) in south-western Western Australia. It has been described as Australia's first treaty (Hobbs & Williams, 2018).

As part of this emerging integration of Noongar culture into Western Australian life, there is a growing need for wider education, recognition and implementation of

Aboriginal knowledge systems (Nannup, 2006; Tucker et al., 2018), ecology and environmental management practices in Australian urban environments (Hopper, 2017). The first reason for doing this is that Indigenous people may find it difficult to sustain traditional knowledge and practices while living in urban centres (PHAIWA, 2015) as modern urban landscapes may not provide adequate places for traditional practices. The bigger picture reason is to find ways that indigenous knowledge can teach the established cities of Australia to find new and useful ways to improve biodiversity management and indeed to create better cities through their biophilic urbanism.

Some urban green infrastructure projects are beginning to incorporate local Aboriginal knowledge in their designs, for example school and public playgrounds (Kirk, 2017; Turner et al., 2017). A number of gardens based on Noongar six seasons have been established in cultural centres, local communities and schools and even in the land managed by private companies. As outlined in this paper the collaborative design process in these emerging projects included the representatives of particular institutions, students, local Aboriginal communities and Elders, artists, landscape designers and landscapers. The recent revival of Indigenous landscaping supports the efforts to re-wild the urban environment and enhance biodiversity, which complies with the biophilic urbanism agenda, but also provides opportunities to deliver biophilic places that facilitate Indigenous practices and restore connections with important (sacred) places. This could potentially facilitate building a deeper and more meaningful connection to the natural world for multicultural communities and hence lead to better biodiversity management.

In 'Indigenous Knowledge in the Built Environment' Jones et al. (2018, p.13) state that '*Indigenous knowledge systems are particularly relevant to the Australian planning and landscape architecture disciplines as it relates to the practice of land planning, management, spatial knowledge exchange and landscape design.'* A similar statement is made regarding the Indigenous concept of time and the seasons. The statement provides a rationale for giving a particularly strong position of including Indigenous landscaping and urban nature management in the biophilic urbanism agenda:

'While Western landscape architecture practice is often driven by the crafting of places for humans and wildlife to enjoin and prosper within, the Aboriginal and Torres Strait Islander peoples' perspective places a greater emphasis upon healing,

nurturing and a long-term perspective about looking after place in anticipation of the return of their ancestors.' (Jones et al., 2018, p. 35).

Indigenous knowledge, values and spirituality could be much more incorporated into the design of urban greenery – parks, private and public gardens, playgrounds, public squares, road verges, stormwater infrastructure. Also, innovative biophilic structures such as green walls and roofs could be designed to reflect Indigenous knowledge, values and spirituality (The Fifth Estate, 2019). This approach can be taken systematically across the urban environment to deliver important aspects of biophilic urbanism.

Indigenous landscaping delivered at the urban scale may provide appropriate space where traditional knowledge and values can be cultivated and as a learning tool for residents of different cultural end ethnical background. This paper hopes to demonstrate how it can be done.

The Noongar people of the South-West corner of Western Australia followed the Six Season calendar for time-keeping and utilizing resources (Collard et al., 2004). The transitions between the seasons rely on the changes in plants and animals' behaviours therefore the time-span of every season is different and does not follow the western calendar. For example, the flowers appearing during certain seasons were signalling the right time to move to another campsite (Lullfitz, 2019; Meagher, 1974).

Noongar Peoples of South-West Australia maintain and use the knowledge of the Six Seasons. In the Noongar language, the seasons are Birak, Bunuru, Djeran, Makuru, Djilba and Kambarang (Figure 1).

Figure 1. Noongar Six Seasons Calendar. Source: https://www.australiassouthwest.com/south-west-inspo/six-seasons-south-west

These Six Seasons are a landscape system used for all cultural purposes: shelter, food, medicine and spiritual nourishment and as a basic requirement for biodiversity management.

Biophilic urbanism is an urban planning and design approach that is aiming to provide cities with a coherent landscaping system that covers all aspects of the built environment. This paper seeks to examine whether the six seasons landscaping system could be applied across the city of Perth in Western Australia, as an example of how cities can relate more to their indigenous roots, how it can help biodiversity management, and what this could mean for the further growth of biophilic urbanism as a professional practice.

5. Stages in the growth of awareness in six season Noongar landscaping in Western Australia.

Three stages are outlined of the modern history of Western Australia focussing on how the new settlers dealt with the Noongar landscape, with illustrations of each stage.

5.1 Early setting aside

The British colony of Western Australia was established in 1826 and began settling in 1829 as a place where a thriving agriculture was considered to be possible as the trees were so large. It did not take long to find that European perceptions were not appropriate about the nature of the landscape (Seddon, 1972). The eucalypts had ways of surviving on deeply leached soils even sands; and the clay soils were not as productive as Hampshire in Britain. But despite the inability to thrive agriculturally, there were early settlers who recognised the extraordinary biodiversity and began to understand the different six season flowering regimes of this biodiversity hotspot as its now known. From very early times the knowledge of where to find flowering plants (and their associated insects, birds and mammals) came from aboriginal sources. The local botany was collected and classified by Georgiana Molloy who became totally fascinated by its incredible diversity and used indigenous knowledge to find the different flowering times for each species she collected (Barry, 2016; Hasluck, 1955; Lines, 1994).

Although the settlers brought many foreign cultivars to their newly established farms and domestic gardens, they also started to discover and learn about the local species and the local ecology. The different soils and climate led to significant problems just feeding themselves and little if any used indigenous food sources. Botanists often succeeded at propagating native plants, building native gardens, and sharing their knowledge with others (Lines, 1994).

The new colony found gold in the 1890's and the main city of Perth grew rapidly. Early planners and politicians who were planning the city found the space to set aside some special native bush in various places, including Kings Park in the heart of the central business district. Kings Park however was not turned into an English park as in Melbourne and Sydney but was left in its native state and has been managed ever since for that purpose (Seddon & Ravine, 1986) – see Figure 2. The benefits of having an Indigenous area at the heart of a city set in motion a history of recognising that the six-season landscape management of the Noongars was

something to preserve (Seddon, 1972). The Park was also set up as a centre of expertise on native flora.

Figure 2. The view to Kings Park in Perth, Australia. Source: Peter Newman

The city was of course a place of its time in being a pioneer culture with the need to conquer the new people and place (Bolton, 2008). But the other more sensitive side of being aware of the indigenous people and their place-based culture was also evident though not as well developed in the practices and planning of the city during its first hundred years.

5.2 Regenerating cleared public land

By the second half of the 20th century town planning had begun to designate the importance of natural spaces in the landscape. Joanna Seabrook, Hazel Dempster, Alex George, Stephen Hopper, and George Seddon, amongst others, became passionate about Western Australian unique flora and shared their passion by helping to discover and systematize collections of Australian plants, establish native and botanical gardens, and contribute to natural environment conservation strategies to protect the species and the local landscapes (Dempster, 2002; Hopper

& Gioia, 2004; Seddon, 2005). Seddon (1972) in particular was very influential on how the city needed to incorporate nature and indigenous perspectives into its planning to create a ‘sense of place’.

Several key areas of public space began to be regenerated, essentially by allowing it to regenerate itself with a little help from weed control where needed. A good example is the Wireless Hill Park which today is a thriving landscape of native plants after its role as a space for the first wireless transmissions was no longer needed and the completely cleared space was regenerated with native bush. There has been a continuing involvement of indigenous expertise in managing this space and other native bush around the city (see Figure 3).

Figure 3. Photograph of Noel Nannup in Walyunga. Credit: Zal Kanga

The largest legacy of this period is the regeneration of the Swan River foreshores. A regulation was part of the new town planning scheme in 1955 that asserted all land on the river’s edge must be returned to the crown within 50 meters of the river’s edge. This land was revegetated mostly with native species and the occasional small park and today is a very popular continuous cycle-way/walk-way for over 80 kms on either side of the river (see Figure 4).

Figure 4. The embankments of Swan River. Credit: Credit: Peter Newman

That these areas were considered better to be turned into indigenous landscapes was a part of the growing culture of seeing native plants as better for biodiversity and also for functional purposes such as green infrastructure in water management and slowing down erosion of river edges. This has been clearly demonstrated by the regeneration of Point Fraser where native vegetation was used to create a storm water treatment area and the reconstitution of a soft interface between land and water (see Figure 5).

Figure 5. Point Fraser. Credit: Peter Newman

In this late 20th century period many domestic and public native gardens emerged and helped to establish the native landscaping principles which are used in towns and cities across Western Australia to build green urban infrastructure: street verges, parks, squares, public gardens, and riverbanks. However, this continued to be in conflict with the modern global trends and gardening fashions influencing individual choices. Perth was not only influenced by British perceptions of nature but many multi-cultural perceptions of the rapidly growing population who were attracted from across the world to work in the mining-based economy and its knowledge-based centre in Perth. The deepest traditions of British landscapes meant private gardens often featured monocultures of lawns and non-native plant species, but many other garden types have emerged. Despite this multiculturalism there was a growing sense that the indigenous plants were special and contributed to the sense of place for everyone. Thus the growth of the native plant industry and their cultural value continued to grow and to assert that for six seasons in Perth and its region, there were flowers that could be made part of any garden, street or a local park. However this was not usually done using indigenous interpreters.

5.3 Landscaping the whole city

In the 21st century there has been a dual increase in the role of native plants in landscaping and the role of indigenous culture in interpreting the landscape. The growth in native plant nurseries, native street tree policies as part of municipal garden strategies, and community interest in how to plant and maintain native gardens, has become a feature of urbanism in Perth. At the same time there has been an increase of interest in the use of indigenous Noongar Six Seasons interpretation of landscaping amongst educational institutions and communities; this is for both landscaping and because of an inherent interest in integrating indigenous culture that helps us better understand our place (Collard et al., 2004).

A number of public and private gardens have emerged using the ecological and cultural principles of the Six Seasons (ATCO, n.d.; City of South Perth, 2019; Shire of York, n.d.; Watkins, 2017) some of which are outlined below. Many primary and secondary schools in Western Australia have established their own Six Seasons Gardens and use the space for educational and cultural purposes (Kirk, 2017; Wheatbelt NRM, 2016). A Six Seasons garden at a Primary School in Manning was established in connection with the local government's Urban Forest Strategy (City of South Perth, 2019).

King's Park now offers educational programs on the Noongar Six Seasons (Botanic Gardens and Parks Authority, n.d.). Aboriginal presenters share their knowledge of the Six Seasons and traditional Noongar life while taking the students for a walk in the gardens of King's Park. One of the educational trails, The Boodja Gnarning Walk, captures some of the Noongar knowledge and explores Noongar use of the land. A number of culturally significant native plants can be found along the tracks of this walk. Students are engaged in a variety of cultural activities traditionally associated with each season, such as plant uses, hunting, language, art, dance and traditional games.

Indigenous author on this paper Noel Nannup Karda, runs educational tours in Perth and its regions as outlined in Box 1.

Box 1 The Carers of Everything (Moondang-ak Kaaradjiny)

I have a science degree which enables me to understand how the world is understood to work by people in the tradition of modern western science. I am also an elder in the Noongar tradition and my totem 'Karda' is the race-horse goanna. I try to integrate the western knowledge and the Noongar knowledge (Robertson et al., 2017). In the Noongar tradition I have a perspective shaped by people who have lived here for so long even modern western science finds it hard to be specific. It's a long time. Multiple generations have thus been passing on their knowledge through stories and songlines and how to simply survive through the Noongar six seasons, using all the fruits of the landscape for this gift of life (Robertson et al., 2019).

I run guided tours along songlines showing how we can gather intuitive knowledge from the bush and from listening to The Carers of Everything (Moondang-ak Kaaradjiny) (Nannup, 2006) which are the spirits that remain from previous time and are able to give us the knowledge that enables us to care for the land and the community. We also go camping so that we can sit around a fire and yarn about the stories in the area.

At the University of Western Australia I help to run a gathering at the start of each of our six seasons, for staff and students, that helps to orient ourselves to the next two months of weather, plant flowering and related stories. This is held in the Business School. It attracts considerable interest as people are looking for a better understanding of our place and how to be more respectful of those who went before us.

At the same time as this increased interest in indigenous landscaping, there has been a growth in the simple use of native plants and especially trees to create an urban forest. Several new suburbs have used native plants with the new residents ensuring that in every street there were plants that would flower in all six seasons thus bringing insects and birds all year around. Some suburbs now have almost completely created a closed canopy of native forest trees that enable the city to be cooled in summer and provided with insects and birds following flowering plants at every stage of the year (see Figure 6).

Figure 6. Urban forest in Subiaco Credit: Peter Newman

There are many local radio and TV shows on gardening that feature the importance of native plants. There are now over twenty restaurants that provide Noongar food on their menus and one ‘Wildflower’ has an entirely local menu that follows the six seasons. There are even biophilic gardens of native plants in wetlands built on top of car parks (Figure 7) where once Indigenous wetlands were used as a major food source (Byrne, 2006).

Figure 7. Cultural Centre Wetland in Northbridge, WA. Credit: Peter Newman

The biodiversity of Perth itself is very high and includes over 200 endemic species of orchid (Hoffman et al., 2019) and this movement to increase the use of native plants in landscaping has been extremely popular. However it has not yet been fully integrated into indigenous culture so this may be the next phase for the city.

6. Six Season Case studies

The paper examines some indigenous landscape case studies to illustrate the concepts presented. The gardens have been studied to derive principles that would then inform and facilitate the delivery of biophilic urbanism based on indigenous landscaping.

The selected case studies are based in Western Australia. Two case studies are Aboriginal Six Seasons Gardens - Ballardong Noongar Six Seasons Garden in York (31°53'33.5"S, 116°46'32.7"E) that occupies the area of 2500m² (Figure 8) and Muminbulah Wilak Six Season Garden in Jandakot (32°06'49.1"S, 115°51'32.0"E) built on the grounds of the ATCO Gas company (Figure 9). The area of this garden is approx. 3000m². The third garden is a native urban garden - The Bushland

Garden in York (31°53'05.5"S 116°45'55.4"E) that occupies the area of approx. 12000m² (Figure 8).

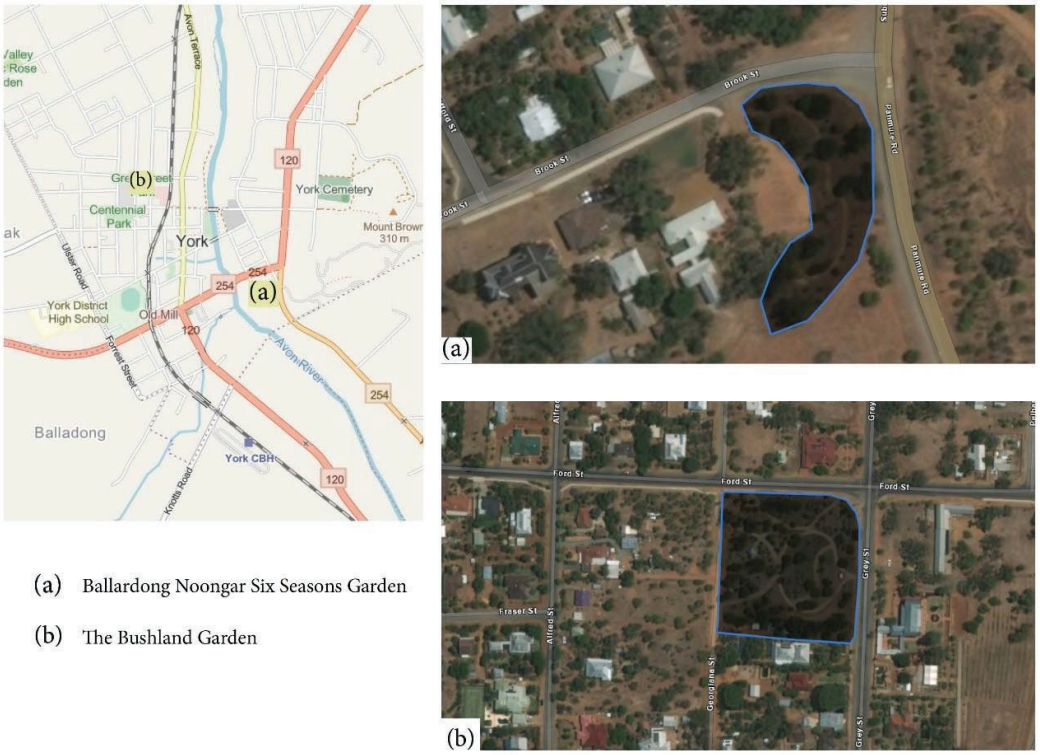


Figure 8. The location of the case studies in York, Western Australia: (a) Ballardong Noongar Six Seasons Garden, (b) The Bushland Garden. Maps derived from ArchGIS database by ESRI Australia Pty. Ltd. Credit: Agata Cabanek

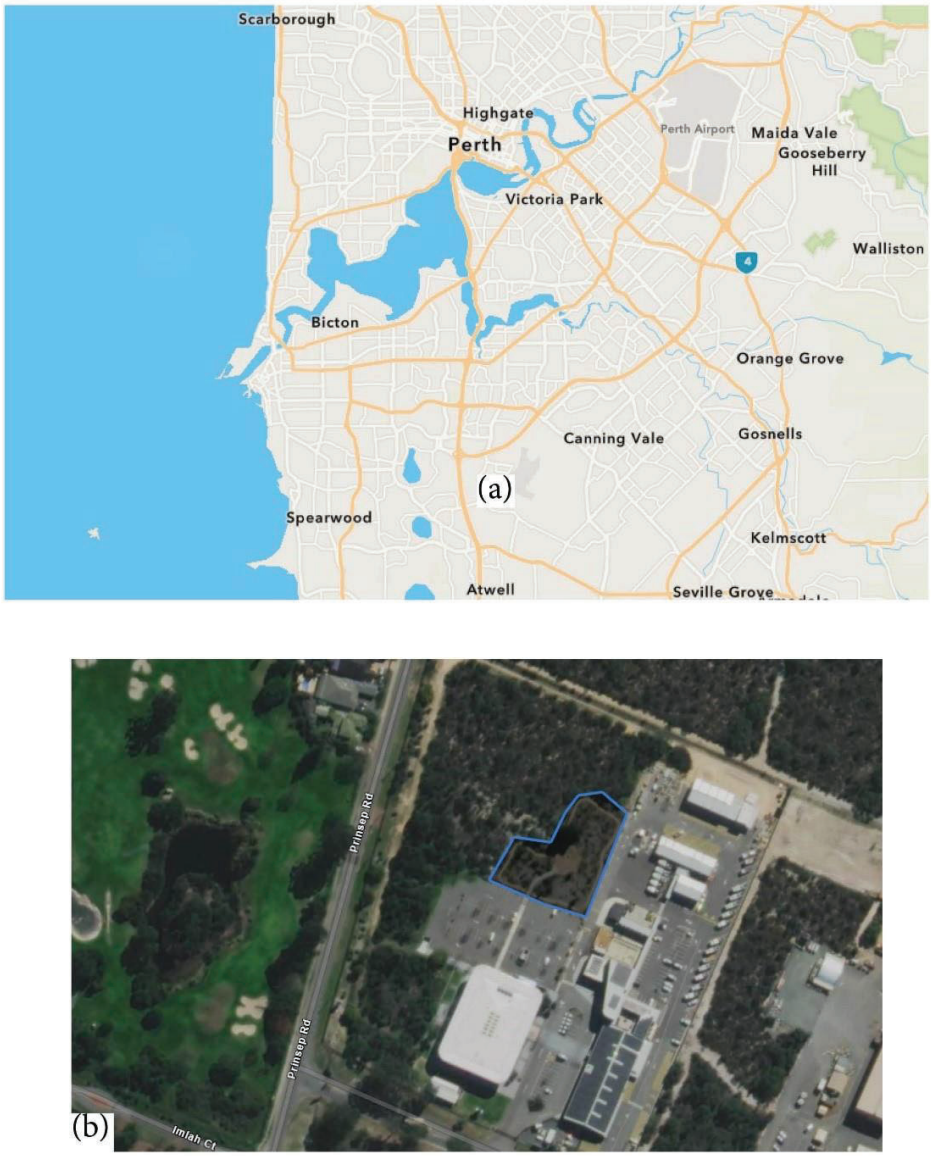


Figure 9. The location of the case study in Jandakot, Western Australia: (a) The Muminbulah Wilak Six Seasons Garden, (b) The ATCO Gas Depot site with the Garden outline (in blue). Maps derived from ArchGIS database by ESRI Australia Pty. Ltd. Credit: Agata Cabanek

6.1 Ballardong Noongar Six Seasons Garden

The garden was established in 2009 on the grounds of the Residency Museum in York, Western Australia. The project was founded through a Wheatbelt Natural Resource Management Network Incentive Development and Support Grant and the Shire of York (Wheatbelt NRM, 2016). The garden was a collective effort of the Wheatbelt NRM, the Ballardong Noongar community, a local high school, individual and corporate sponsors and volunteers. The design concept is based on Noongar Six Seasons which are characterised and divide by natural changes in weather conditions and seasonal cycles of flora and fauna. As per the information provided by the Residency Museum, the project is a symbolic garden walk and it represents koora-korra [the past], yey [the present] and mila [the future] of Ballardong Noongar Budjar and its meaning to the Ballardong Noongar people (Ballardong Noongar Six Seasons Garden Walk, n.d.).

The main feature is the bidi (path) which is divided into six sections (Figure 10). Each section is marked with symbolic boya (river-stones) painted by the local high school students (Figure 11). The boya depict local plants and form the Noongar names for each seasons (Shire of York, n.d.).

Figure 10. The bidi [path] and native shrubs and trees. A corten-steel model of waitj [emu] and its young can be seen in the centre. Symbolic camp circles in the bottom-right corner. Credit: Agata Cabanek

Figure 11. The boya (symbolic ceramic river-stones) decorated with pressings of local plants. The stones form the word for the Noongar season Djeran. Credit: Agata Cabanek

The native flora and fauna bear traditional meaning and importance in this garden. When the visitors follow the footpath, they learn about the plants, animals and activities occurring in particular seasons. The particular plants would serve as the season changing indicators, food, medicine or water source. Animals depicted in the garden were traditionally valuable food sources in particular seasons but also important spiritual and cultural symbols and totems. The animals hunting for food and gathering fruits and berries were done in the correct seasons in line with traditional Knowledge passed on by each generation (Collard et al., 2004).

The main feature - the bidi (path) - is divided into six sections. The bidi (path) symbolises Bilya [the Avon River] winding through the Avon Valley. The Six season garden in York plays a symbolic role in order to educate the visitors on spiritual, ecological and cultural level. The garden is a ‘living narrative’ undergoing transformations with the seasons and years passing.

There are another two symbolic gardens within the grounds of the Residency Museum. A small kitchen garden near the cottage is named Settlers’ Kitchen Garden and it was established in 2006 in memory of Phillis Rogers, a Museum

volunteer (Figure 12). Also, there is the Waterwise Garden established in 2006 which includes a variety of native and non-native plant species.

Figure 12. The Settlers' Kitchen Garden established in 2006. Credit: Agata Cabanek

The symbolic placement of the Six Seasons Garden (Figure 13) enforces its ecological and educational importance. The Settlers' Kitchen Garden established near the cottage symbolises the knowledge that arrived with first European settlers. Next is the Waterwise Garden which symbolises the embrace of native flora and Indigenous knowledge of the plant species and their use. The Ballardong Noongar Six Seasons Garden comes as the last one established (2009) and symbolises a wider embrace of the Indigenous knowledge, culture and spirituality. Every plant, stone, symbol has its cultural and spiritual meaning.

Figure 13. Mapping of the three gardens adjacent to Residency Museum in York: (a) The Settlers' Kitchen Garden, (b) The Waterwise Garden, (c) The Ballardong Noongar Six Seasons Garden (not to scale). Credit: Agata Cabanek

6.2 Muminbulah Wilak Six Seasons Garden

Muminbulah Wilak Six Season Garden, built in the Jandakot Operation Centre, is the company's private garden, a cultural education tool, telling the story of Noongar Culture and the role the seasons, local native vegetation and animals played in the history, and traditions of the Noongar people (WA Parks Foundation, 2021). The idea of establishing the garden at the ATCO depot in Jandakot was one of the Reconciliation strategies (actions) adopted by the company in 2018 (ATCO, 2018).

Jandakot is based on the Banksia Sand Plains where many species of Banksia can be found. It is a plant of high significance to the Noongar people who traditionally used it as food or for fire starting. The Six Season Garden is surrounded by the remnant Banksia bushland that provides backdrop for the garden area (Figure 14).

Figure 14. The footpath and planting beds (left). The remnant Banksia bushland forms the backdrop to the garden. Credit: Agata Cabanek

The design was inspired by a painting from a local Indigenous Artist Deborah Bonar (ATCO, 2018). The painting was presented to the ATCO representatives and a detailed garden design was later developed by Denice Kickett in consultation with the local Elders and was named after her Nyoongar name – Muminbulah Wilak – Spirit of the Land. The painting symbolises the six seasons and the flora, fauna and human activities characteristic to those seasons. The garden was installed by appointed local Indigenous landscaping companies (J. Scriven, personal communication, June 20, 2018).

The design of the Muminbulah Wilak Six Seasons Garden was based on the knowledge of the Noongar Six Seasons. The plants palette correlated with the plants that are available for food, medicine, shelter and other resources during each season.

The entry to the Garden is marked by two sculptures resembling boomerangs and a welcome message engraved in them (Figure 15).

Figure 15. The entrance to the Garden marked by two boomerang sculptures. Credit: Agata Cabanek

The footpath directs visitors to the central point of the garden with a circular water feature (Figure 16). The space around the water feature serves for gatherings and events. The pavement resembles a map of Noongar Boodjar (Noongar Country) and the Fourteen Tribal Language Groups (Collard et al., 2004). This central contemplation area is bordered by sculptured walls (seating) which symbolise the Wagyl, the rainbow serpent - the creator from of the Aboriginal dreamtime (ATCO, 2018).

Figure 16. The central water feature and the wavy wall symbolising the Wagyl (Serpent). The pavement based on the map showing the residing sites of the 14 clans in South West Australia. Credit: Agata Cabanek

The garden is divided into six sections. Starting from the water feature the division marks radiate towards the garden beds symbolising each season. A circular footpath guides the visitors through the garden where they learn about the landscapes, plants, animals, weather and activities characteristic to each season. The Audio Garden Tour is available for visitors via their smartphone as they walk through the Garden. The tour was developed and recorded by Aboriginal Productions and Promotions and music was supplied by Dr Richard Walley (ATCO, n.d.; J. Scriven, personal communication, June 20, 2018).

The garden serves as a cultural and educational tool. A space for sharing stories and history of the oldest living culture in the world. A tool to educate those who seek a better understanding and appreciation of Culture and Country. The ATCO Company uses this space to welcome guests to their centre. As a part of the community engagement plan, school groups are often invited to visit the Six Seasons Garden and participate in special educational program (J. Scriven, personal communication, June 20, 2018).

6.3 The Bushland Garden

The Bushland Garden in York (Western Australia) is a community-driven urban open space featuring a wide range of native plants naturally growing in the Wheatbelt region. The site was once a clay pit for brick making and became an eye-sore wasteland after the Meckering earthquake in 1968 when rubble from the demolished York Royal Hotel was buried there. Two local residents - Joanna Seabrook and Adelphe King – decided to turn this vacant lot into a bushland garden. Between 1993 and 2002 the local volunteers planted native species, constructed the footpaths, shelters and a Memory Corner dedicated to one of late volunteers (Figure 17). However, due to lack of external funding, the garden deteriorated and in 2005 the York Branch of the Widlflower Society decided to assume responsibility for the ongoing maintenance and development of the existing garden (E. Ayling, personal communication, April 22, 2021). Since the transition, the garden attracted many groups and local authorities, including Wheatbelt Natural Resource Management, York LCDC, Green Corps, the York Garden Club, the LEAP scheme, and the York Shire Council that contributed to its maintenance, and promote as an important green urban space in York.

Figure 17. A memory corner and new plantings. Credit: Agata Cabanek

One of the main objectives for the establishment of the garden was to promote and encourage the growing of local plants with a particular focus on native species from York Shire. It was not set up as a demonstration of six seasons flowering but is so extensive in its collection of native plants it does in fact have many features of a six seasons garden. However it is not making the most of this cultural connection (Watkins, 2017).

The Bushland Garden is an example of a successful grassroots initiative which could be replicated anywhere but it misses the opportunity to bring a cultural dimension of Indigenous landscaping. How important is this?

7. Why enable Indigenous landscaping?

The following table sets out the qualities of Indigenous Gardens (like Ballardong and Muminbulah Wilak Six Seasons gardens) and Local Native Gardens (like the Bushland Garden in York).

	Indigenous Gardens	**Local Native Garden**
Purpose	• Cultural expression; • Profound connection with land, fauna and flora, abiotic elements of landscape; • Stewardship of indigenous culture and environmental and spiritual knowledge; • Places for gatherings, cultural and spiritual events, and healing; • Providing educational space for students, children and adults; • Providing space for memorials and acknowledgments and recognitions;	• Promoting native flora to expand use in private gardens; • Natural environment conservation efforts; • Educating about native plants, planning, display arrangements to encourage the transformation of landscaping and gardening practices; • Regeneration of urban wasteland; • Providing a recreational and educational green space in the urbanised environment; • Providing educational space for students – engaging in maintenance, creating a bush-tucker garden;

		• Providing space for memorials and acknowledgments and recognitions;
Design	• Designs are based on Aboriginal Dreaming and Aboriginal Six Seasons. They often include a motif of a journey; • Fauna, flora, and abiotic elements of landscape (rocks, soil, land formations, water) are all significant parts of a garden; • Inclusion of cultural artefacts (sculptures, paintings, weapons); • Symbolic representations of local indigenous history, culture, values and beliefs; • The biological changes occurring in plants and animals during Noongar Six Seasons inform the garden visitors about important events and milestones;	• Planting arrangements are experimental; • Designs are based on Western classical garden display techniques and practices (elements such as garden beds, layered planning arrangements, winding footpaths, pergolas, benches, picturesque views); • Less emphasis on abiotic landscape elements; • Strong emphasis on creating a waterwise garden;
Flora, fauna and abiotic elements	• Plants and animals and abiotic landscape elements bear cultural and spiritual significance in an indigenous garden; • Use of plants and planting arrangements are based on Indigenous environmental, cultural and spiritual knowledge; • The plant species are chosen for their medical and nourishing qualities, practical use, cultural and spiritual meaning and values;	• Plants are selected for their aesthetics and ecological qualities; • Plants arrangements to create a waterwise garden that is easy to maintain;

Table 1. Historic preservation, reclamation and conservation efforts to acknowledge Indigenous and European heritage.

There are many reasons for including both approaches into any city but there are good extra reasons for prioritizing Indigenous landscaping. There are several reasons why biophilic urbanism would want to try and incorporate this inclusive approach to indigenous landscaping:

1. **Cultural value.** Cultural immersion into landscapes enables a range of important benefits to the whole city as it is the foundation of a sense of place (Seddon, 1972). When native plant projects are seen as the realm of those with exclusive technical knowledge or the money to build monuments to their exclusive source of enjoyment, then the native plant movement is not going to be able to touch people in the same ways as one that features more meaningful interpretation of the plants in their use over deep history.

2. **Educational value.** To have inclusive landscaping where Indigenous cultural uses of plants are integrated into every part of a planned project will involve a range of educational outcomes on planting local plants and promoting knowledge on how they can be used as food, spices, medicine, production of clothes, utensils, and tableware. New inclusive projects will provide insights as to how such applications of indigenous landscaping can assist with fire management and water management as well as the critically important facts as to what enabled the biodiversity to be so rich for so long.

3. **Professional value.** Landscaping throughout a city can enable the whole design profession to have a role in creating a more biodiversity-centred city. The potential for the whole city of Perth to return to its original status as a place that thrives around its six seasons of plants in their cycles of flowering would provide a new vision for the design professions. This will depend on the extent to which indigenous landscaping is actually understood and transferred into landscape design and practice as a new kind of biophilic urbanism related to Perth and all its cultures, especially the one that understood its local plants for millennia.

Such an approach could be used in any city so we return to discussing why this more inclusive approach to indigenous cultures can assist in biophilic urbanism, based on the insights from the case studies and the above conclusions.

8. How does indigenous landscaping help biophilic urbanism?

Biophilic urbanism has developed an approach that shows how urban vegetation in, on and between buildings has multiple benefits especially for the economic benefits of green infrastructure, the human health and welfare benefits from being closer to nature, and the deeper motivation for many which is to increase the potential for saving and regenerating biodiversity (Beatley & Newman, 2013; Marinelli, 2021; Sanderson et al., 2018). So where does indigenous insight fit into this?

Three key reasons can now be given:

1. **The importance of place**

Biophilic urbanism stresses the importance of place in its rationale. There is a strong rationale for sense of place and belonging to be a major part of how communities are able to thrive and develop the social capital so critical for creating economic capital (Putnam et al, 1994; Nuryani et al., 2018). This is also the basis of thriving cities (Newman & Kenworthy, 1999). The sense of place in a city is bound up in a combination of the physical/natural environment and the social/cultural environment. As Low et al (2005) show, this combination means that the most successful public spaces combine both of these features so the best ones are always multicultural. Biophilic urbanism therefore needs to be inclusive if it is to be successful.

2. **The importance of inclusive culture**

Plants are used in landscaping to create biophilic urbanism. But plants that are there to show off the history of landscape design or a foreign country like Britain's interpretation of this (in the case of Australia) are not going to give the cultural meanings so necessary for a successful sense of place. This also applies to the perceptions of other migrants coming from Europe, Asia, the Americas and Africa in more recent times. Plants that are used in landscaping not just for aesthetics but for cultural and spiritual meanings that are designed to create place, are likely to create a more meaningful and successful biophilic urbanism in the new place where people are now developing a different sense of place. Indigenous meanings are the deepest meanings for a place, especially if they go back as long as they do in Australian history.

3. The importance of biodiversity

The deeper level of biophilic urbanism, the need to conserve and regenerate biodiversity, is also a critical element in why indigenous landscaping needs to be integrated into biophilic design. The need for indigenous insights will gather momentum when the design professions take this on in all that they do. As well as that the commitment to biodiversity management (funding and jobs) are always hard to generate but when the sense of place is brought to life in a city through meaningful and creative involvement of indigenous landscaping in a community-based biophilic proje, the chances of success are greatly increased. Biodiversity needs inclusion if it is to be given a chance of reversing its global decline.

9. Conclusions

This paper has suggested that biophilic urbanism and six season landscaping can inform each other and could help to promote and mainstream Indigenous and native landscaping strategies. This extra human dimension to managing the environment can lead to the enabling of local policies advocating green urban infrastructure and biodiversity management. This is at the heart of biophilic urbanism and can give the delivery of this new and more holistic approach to landscaping, a real boost.

In this paper, we have presented a case study of a bushland community garden in York (Western Australia) that has become a showcase example of how to promote native flora and landscaping techniques that can build more resilient and biodiverse urban landscapes. However, if it were to add an indigenous landscaping component, it would likely have a much deeper impact on the application of native plants to every area of biophilic urbanism in the associated communities who use the area. This is not an isolated example but is symptomatic of many new opportunities that are now appearing for the application of Six Seasons interpretive landscaping as part of biophilic urbanism in the future of Perth.

The future of biophilic urbanism in other cities will depend on whether the design professions have made sufficient contact with the historians, anthropologists and remnant communities from their indigenous past. They will then need to begin making programs that can dramatize the value for all aspects of biophilic urbanism in creating a deeper sense of place for all residents using the same land as those from deep history. We believe this will make a better city but also play a major role in biodiversity management for the planet.

References

Alexandra, J., & Norman, B. (2020). The city as forest - integrating living infrastructure, climate conditioning and urban forestry in Canberra, Australia. *Sustainable Earth*, *3*(1), 10. https://doi.org/10.1186/s42055-020-00032-3

ATCO. (n.d.). *Muminbulah Wilak – Six Season Garden*. Retrieved September 4, 2020, from https://www.atco.com/en-au/our-commitment/community-engagement/community-indigenous-relations/six-seasons-garden.html

ATCO. (2018). *ATCO's vision for reconciliation is building a better Australia, by building better relationships, understanding and trust in partnership with Aboriginal and Torres Strait Islander peoples*. https://www.atco.com/en-au/our-commitment/community-engagement/community-indigenous-relations.html

Australian Government. (2015). *Sustainable Development Goals*. https://www.dfat.gov.au/aid/topics/development-issues/2030-agenda/Pages/sustainable-development-goals

Ballardong Noongar Six Seasons Garden Walk. (n.d.). Retrieved December 4, 2018, from http://www.avonnrm.org.au/documents/nyungar_nrm_dictionary.

Barry, B. (2016). *Georgiana Molloy: The Mind That Shines*. Picator Australia.

Beatley, T., & Newman, P. (2013). Biophilic Cities Are Sustainable, Resilient Cities. *Sustainability*, *5*(8), 3328–3345. https://doi.org/10.3390/su5083328

Birkeland, J. L. (2015). Net positive biophilic urbanism. *Smart and Sustaianble Built Environment*, *5*(1), 9–14. https://doi.org/10.1108/SASBE-10-2015-0034

Botanic Gardens and Parks Authority. (n.d.). *Gnarning Walk*. Retrieved August 31, 2020, from https://www.bgpa.wa.gov.au/kings-park/events/walks-and-tours/self-guided-walks/boodja-gnarning-walk

Byrne, J. (2006). *The green gardener : sustainable gardening in your own backyard*. 138.

Chapman, A. D. (2009). *Number of Living Species in Australia and the World*. https://www.environment.gov.au/system/files/pages/2ee3f4a1-f130-465b-9c7a-79373680a067/files/nlsaw-2nd-complete.pdf

City of South Perth. (2019). *New seedlings to represent Noongar seasons*. https://southperth.wa.gov.au/about-us/news-and-publications/news-and-public-notices/news-detail/2019/08/14/new-seedlings-to-represent-noongar-seasons

Collard, L., Harben, S., & Berg, S. van den. (2004). *Nidja Beeliar Boodjar Noonookurt Nyininy: A Nyungar interpretive history of the use of Boodjar (country) in the vicinity of Murdoch University*.

Connop, S., & Nash, C. (2018). *Blandscaping that Erases Local Ecological Diversity*. The Nature of Cities. https://www.thenatureofcities.com/2018/01/09/blandscaping-erases-local-ecological-diversity/

Daniels, P., El Baghdadi, O., Desha, C., & Matthews, T. (2020). Evaluating net community benefits of integrating nature within cities. *Sustainable Earth 2020 3:1*, *3*(1), 1–15. https://doi.org/10.1186/S42055-020-00025-2

Dempster, H. E. (2002). Weeds or wildfl owers. In H. Spafford Jacob, J. Dood, J. Moore, H. S. Jacob, & J. H. Moore (Eds.), *Thirteenth Australian Weeds Conference papers & Proceedings* (pp. 685–688). RG and FJ Richardson.

Downton, P., Jones, D., Zeunert, J., & Roös, P. (2017). Biophilic Design Applications: Putting Theory and Patterns into Built Environment Practice. *KnE Engineering*, *2*(2), 59. https://doi.org/10.18502/keg.v2i2.596

Gammage, B. (2012). *The Biggest Estate on Earth*. Allen & Unwin.

Hasluck, A. (1955). *Georgiana Molloy: Portrait with Background*. Oxford University Press.

Hes, D., & Du Plessis, C. (2015). *Designing for Hope: Pathways to Regenerative Sustainability*. Routlege.

Hobbs, H., & Williams, G. (2018). The Noongar Settlement: Australia's First Treaty. *Sydney Law Review*, *40*(1), 1–39. https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=00820512&v=2.1&it=r&id=GALE%7CA545146876&sid=googleScholar&linkaccess=fulltext

Hoffman, N., Brown, A., Brown, J. (Orchid enthusiast), & Scott Print. (2019). *Orchids of South-West Australia* (4th ed.). Orchids WA.

Hopper, S. D., & Gioia, P. (2004). The Southwest Australian floristic region: Evolution and conservation of a global hot spot of biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, *35*(Figure 1), 623–650. https://doi.org/10.1146/annurev.ecolsys.35.112202.130201

Hopper, S., Harvey, M. S., Chappill, J., Main, A. R., & Main, B. Y. (1996). The Western Australian biota as Gondwanan heritage - a review. In S. Hopper, J. A. Chappill, M. S. Harvey, & A. S. George (Eds.), *Gondwanan Heritage* (pp. 1–46). Surrey Beatty & Sons.

Ives, C. D., Lentini, P. E., Threlfall, C. G., Ikin, K., Shanahan, D. F., Garrard, G. E., Bekessy, S. A., Fuller, R. A., Mumaw, L., Rayner, L., Rowe, R., Valentine, L. E., & Kendal, D. (2016). Cities are hotspots for threatened species. *Global Ecology and Biogeography*, *25*(1), 117–126. https://doi.org/10.1111/geb.12404

Jones, D. S., Choy, D. L., Tucker, R., Heyes, S., Revell, G., & Bird, S. (2018).

Indigenous Knowledge in The Built Environment A Guide for Tertiary Educators.

Kellert, S. (2016). Biophilic urbanism: the potential to transform. *Smart and Sustainable Built Environment*, *5*(1). https://doi.org/10.1108/SASBE-10-2015-0035

Kellert, S., & Calabrese, E. (2015). The Practice of Biophilic Design. In *www.biophilic-design.com*. www.biophilic-design.com

Kirk, E. (2017, November 1). Cornerstone Christian College Dunsborough. Six Season Garden. *Busselton Mail*. https://www.busseltonmail.com.au/story/5027766/students-plant-six-seasons-garden/

Knapp, C. (2008). *Making Multicultural Places*. https://www.pps.org/article/multicultural-places

Lachowycz, K., & Jones, A. P. (2013). Towards A Better Understanding Of The Relationship Between Greenspace And Health: Development Of A Theoretical Framework. *Landscape and Urban Planning*, *118*, 62–69. https://doi.org/10.1016/j.landurbplan.2012.10.012

Lines, W. J. (1994). *An all consuming passion : origins, modernity, and the Australian life of Georgiana Molloy*. Allen & Unwin.

Low, S. M., Taplin, D., & Scheld, S. (2005). *Rethinking urban parks : public space & cultural diversity*. The University of Texas Press.

Lullfitz, A. K. (2019). *Vegetation Responses to Noongar Land Management Practices in Old and Young Landscapes of South Western Australia*.

Marinelli, J. (2021). *Urban Refuge: How Cities Can Help Solve the Biodiversity Crisis*. https://e360.yale.edu/features/urban-refuge-how-cities-can-help-solve-the-biodiversity-crisis

McDonald, R. I., Beatley, T., & Elmqvist, T. (2018). The green soul of the concrete jungle: the urban century, the urban psychological penalty, and the role of nature. *Sustainable Earth 2018 1:1*, *1*(1), 1–13. https://doi.org/10.1186/S42055-018-0002-5

Meagher, S. J. (1974). The food resources of the Aborigines of south-western Australia. *Records of the Western Australian Museum*, *3*, 14–65.

Nannup, N. (2006). *Moondang-ak Kaaradjiny*. Batchelor Press.

Newman, P. (2014). Biophilic urbanism: a case study on Singapore. *Australian Planner*, *51*(1), 47–65. https://doi.org/10.1080/07293682.2013.790832

Newman, P., & Kenworthy, J. (1999). *Sustainability and cities : overcoming automobile dependence*. Island Press.

NRM, P. (n.d.). *Perth NRM invites comment on The New Normal*. Retrieved September 18, 2020, from https://www.perthnrm.com/blog/2019/11/05/perth-nrm-invites-comment-on-the-new-normal/

Nuryani, N. N. J., Satrawan, D. P. R., Gorda, A. A. N. O. S., & Martini, L. K. B. (2018). Influence of Human Capital, Social Capital, Economic Capital towards Financial Performance & Corporate Social Responsibility. *International Journal of Social Sciences and Humanities*, *2*(2), 65–76. https://doi.org/10.29332/ijssh.v2n2.128

Pascoe, B. (2018). *Dark Emu*. Magabala Books.

PHAIWA. (2015). *The West Australian Indigenous Storybook: Celebrating & Sharing Good News Stories, The Perth & Peel Edition*. internal-pdf://0337610048/PHAIWA 2015 The-WA-Indigenous-Storybook-7th-Edition2.pdf

Robertson, F., Nannup, N., & Barrow, J. (2019). *Great Journeys undertaken by Aboriginal people in ancient times in Western Australia*. Batchelor Press.

Robertson, F., Nannup, N., Stasiuk, G., & Hopper, S. (2017). *Nyoongar Boodja: Koomba Bardip Kooratan*. Batchelor Press.

Sanderson, E. W., Walston, J., & Robinson, J. G. (2018). From Bottleneck to Breakthrough: Urbanization and the Future of Biodiversity Conservation. In *BioScience* (Vol. 68, Issue 6, pp. 412–426). Oxford University Press. https://doi.org/10.1093/biosci/biy039

SBEnrc. (2011). *Considering the Application of Biophilic Urbanism*.

Secretariat of the Convention on Biological Diversity. (2020). Global Biodiversity Outlook 5. In *Montreal, Canada*.

Seddon, G. (1972). *Sense of Place. A response to an Environment, the Swan Coastal Plain, Western Australia*. University of Western Australia Press. https://philpapers.org/rec/SEDSOP

Seddon, G. (2005). *The Old Country: Australian Landscapes, Plants and People*. Cambridge University Press. https://books.google.com.au/books/about/The_Old_Country.html?id=cvxm3-7iH2oC&source=kp_book_description&redir_esc=y

Seddon, G., & Ravine, D. (1986). *A city and its setting : images of Perth, Western Australia*. Fremantle Arts Centre Press.

Shire of York. (n.d.). *Ballardong Noongar Six Seasons Garden Walk*. Retrieved August 27, 2020, from https://www.york.wa.gov.au/museum/visit/museum-ballardong-noongar-six-seasons-garden-walk.aspx

The Fifth Estate. (2019). *Redfern's new indigenous rooftop teaching communities*

about place. https://www.thefifthestate.com.au/innovation/building-construction/redferns-new-indigenous-rooftop-teaching-communities-about-place/

Tucker, R., Low Choy, D., Heyes, S., Revell, G., & Jones, D. (2018). Re-casting terra nullius design-blindness: better teaching of Indigenous Knowledge and protocols in Australian architecture education. *Int J Technol Des Educ*, *28*, 303–322. https://doi.org/10.1007/s10798-016-9389-5

Turner, A., Wilson, K., & Wilks, J. L. (2017). Aboriginal Community Engagement in Primary Schooling: Promoting Learning through a Cross-Cultural Lens. *Australian Journal of Teacher Education*, *42*(11), 42. https://doi.org/10.14221/ajte.2017v42n11.7

United Nations. (2015). *United Nations General Assembly. Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/1). Resolution adopted by the General Assembly on 25 September 2015*. https://doi.org/10.1163/157180910X12665776638740

WA Parks Foundation. (2021). *Muminbulah Wilak – ATCO's six seasons garden*. https://www.ourwaparks.org.au/muminbulah-wilak-atcos-six-seasons-garden/

Watkins, B. (2017). *York Bushland Garden*. Wildflowwer Society WA. https://www.youtube.com/watch?v=VgOi4Jg8DO4&t=13s

WEF. (2020). *Nature Risk Rising : Why the Crisis Engulfing Nature Matters for Business and the Economy* (Issue January).

Wheatbelt NRM. (2016). *Establishing the 'Six Seasons' Garden*. https://www.wheatbeltnrm.org.au/whats-happening/news/aboriginal-nrm/establishing-'six-seasons'-garden

Yazdani, N., & Lozanovska, M. (2014). Representation of multiculturalism in urban green spaces: a review of immigrants' experiences in Australia. *UHPH 2014 : Landscapes and Ecologies of Urban and Planning History : Proceedings of the 12th Australasian Urban History Planning History Conference*, 851–864. http://dro.deakin.edu.au/view/DU:30061642

Declarations:

Ethics approval and consent to participate

The research presented and reported in this paper was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research – updated May 2020. The proposed research study received human research ethics approval from Curtin University Human Research Ethics Committee, approval Number: HRE2016-0258.

Consent for publication

Not applicable

Availability of data and materials

The dataset used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare they have no competing interests.

Funding

This research funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative.

Authors' contributions

Conceptualisation, AC; Methodology, AC,PN; Investigation, AC; Analysis AC, PN; Original draft preparation, AC; Review & Editing PN, AC, NN. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

Affiliations

Agata Cabanek, Prof Peter Newman, are from Curtin University Sustainability Policy Institute, Perth, Australia. Dr Noel Nannup is a Noongar Elder from Perth, Western Australia

Appendix H: Copyright statement and copyright release for published material

I have obtained permission from the copyright owners to use any third-party copyright material reproduced in the thesis, or to use any of my own published work (e.g. journal articles) in which the copyright is held by another party.

WIT PRESS
Ashurst Lodge, Ashurst, Southampton, SO40 7AA
Tel: 023 80 293223 Fax: 023 80 292853 Email: witpress@witpress.com Web: https://www.witpress.com

15 April 2021

Dear Ms Cabanek,

In response to your recent enquiry; WIT Press hereby gives you permission to use the requested copyright material as long as the following conditions are adhered to...

In addition to the full bibliographical being cited in the list of references: alongside any copyright material embedded in the text the following must appear viz:

(1) If from a TRANSACTIONS Volume...

'Courtesy of WIT Press from [e.g. WIT Transactions on Ecology and the Environment Volume 124, 2009, page 110]'

(2) If from a JOURNAL Issue...

'Courtesy of WIT Press from [e.g. International Journal of Design & Nature and Ecodynamics Volume (6), No. (1), March 2011, page 56]'

(3) If from a WIT Press book...

'Courtesy of WIT Press from the book [e.g. G. Lorenzini, C. Biserni and G. Flacco: Solar Thermal and Biomass Energy, 2010, page 76]'

Yours sincerely

Simon Ibbotson,
WIT Press

AW: request for copyright clearance
Bookpermissions <bookpermissions@springernature.com>
Wed 21/04/2021 18:20
To:

- Agata Cabanek <agata.cabanek@postgrad.curtin.edu.au>

Dear Agata Cabanek,

Thank you for your recent email. Per your retained rights you can reuse your chapter in your thesis/dissertation without obtaining permission from us.

Please include full acknowledgement to the original source.

Best regards,

Sara Martínez
Book Permissions

SpringerNature
Tiergartenstr. 17, 69121 Heidelberg, Germany
sara.martinezgarcia@springernature.com
http://www.nature.com
http://www.springer.com
http://www.palgrave.com

Von: Agata Cabanek [mailto:agata.cabanek@postgrad.curtin.edu.au]
Gesendet: Montag, 12. April 2021 07:46
An: Bookpermissions <bookpermissions@springernature.com>
Betreff: request for copyright clearance

[External - Use Caution]

To whom it may concern,

It is my understanding that your organisation is the copyright holder for the following material:

Newman P., Cabanek A. (2020) Bioregional Planning and Biophilic Urbanism. In: Fanfani D., Matarán Ruiz A. (eds) Bioregional Planning and Design: Volume I. Springer, Cham. https://doi.org/10.1007/978-3-030-45870-6_7

I would like to reproduce an extract of this work in a doctoral thesis, which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is biophilic urbanism I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.
I would like to reproduce the article in the appendix of the thesis in full with your permission.
Once completed, the thesis will be made available in the online form via Curtin University's Institutional Repository espace@Curtin. The material will be provided strictly for educational purposes and on a non-commercial basis.
I would be most grateful for your consent to the copying and communication of the work as

proposed.
I look forward to hearing from you and thank you in advance for your consideration of my request.

Kind regards,

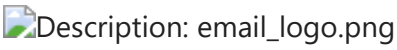
Agata Cabanek

Agata Cabanek, M. Land. Arch.

Doctoral Researcher | Lecturer
Curtin University Sustainability Policy Institute (CUSP)

Curtin University

Mobile | +61 450744016
Email | agata.cabanek@postgrad.curtin.edu.au
Web | https://sustainability.curtin.edu.au/



From: https://www.mdpi.com/authors/rights accessed on the 27th of September 2021

Copyrights

1. **Copyright and Licensing**

For all articles published in MDPI journals, copyright is retained by the authors. Articles are licensed under an open access Creative Commons CC BY 4.0 license, meaning that anyone may download and read the paper for free. In addition, the article may be reused and quoted provided that the original published version is cited. These conditions allow for maximum use and exposure of the work, while ensuring that the authors receive proper credit.

In exceptional circumstances articles may be licensed differently. If you have specific condition (such as one linked to funding) that does not allow this license, please mention this to the editorial office of the journal at submission. Exceptions will be granted at the discretion of the publisher.

2. **Reproducing Published Material from other Publishers**

It is absolutely essential that authors obtain permission to reproduce any published material (figures, schemes, tables or any extract of a text) which does not fall into the public domain, or for which they do not hold the copyright. Permission should be requested by the authors from the copyright holder (usually the Publisher, please refer to the imprint of the individual publications to identify the copyright holder).

Permission **is required** for:

1. Your own works published by other Publishers and for which you did not retain copyright.
2. Substantial extracts from anyone's works or a series of works.
3. Use of Tables, Graphs, Charts, Schemes and Artworks if they are unaltered or slightly modified.
4. Photographs for which you do not hold copyright.

Permission **is not required** for:

3. Reconstruction of your *own* table with data already published elsewhere. Please notice that in this case you must cite the source of the data in the form of either "Data from..." or "Adapted from...".
4. Reasonably short quotes are considered *fair use* and therefore do not require permission.
5. Graphs, Charts, Schemes and Artworks that are completely redrawn by the authors and significantly changed beyond recognition do not require permission.

6. **Obtaining Permission**

In order to avoid unnecessary delays in the publication process, you should start obtaining permissions as early as possible. If in any doubt about the copyright, apply for permission. MDPI cannot publish material from other publications without permission.

The copyright holder may give you instructions on the form of acknowledgement to be followed; otherwise follow the style: "Reproduced with permission from [author], [book/journal title]; published by [publisher], [year].' at the end of the caption of the Table, Figure or Scheme.