Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure

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Abstract

If a 'Renaturing of Cities' strategy is to maximise the ecosystem service provision of urban green infrastructure (UGI), then detailed consideration of a habitat services, biodiversity-led approach and multifunctionality are necessary rather than relying on the assumed benefits of UGI *per se*. The paper presents preliminary data from three case studies, two in England and one in Germany, that explore how multifunctionality can be achieved, the stakeholders required, the usefulness of an experimental approach for demonstrating transformation, and how this can be fed back into policy. We argue that incorporating locally contextualised biodiversity-led UGI design into the planning and policy spheres contributes to the functioning and resilience of the city and provides the adaptability to respond to locally contextualised challenges, such as overheating, flooding, air pollution, health and wellbeing as well as biodiversity loss. Framing our research to encompass both the science of biodiversity-led UGI and co-developing methods for incorporating a strategic approach to implementation of biodiversity-led UGI by planners and developers addresses a gap in current knowledge and begins to address barriers to UGI implementation. By combining scientific with policy learning and defined urban environmental targets with community needs, our research to date has begun to demonstrate how nature-based solutions to building resilience and adaptive governance can be strategically incorporated within cities through UGI.

Highlights

- Three case studies of novel urban green infrastructure implementation are presented
- Effective multifunctional approaches to green infrastructure design demonstrated
- That biodiversity should be an intrinsic consideration in design is illustrated
- Local context and multi-stakeholder approach to design and management are integral

Key words: *Green infrastructure policy, multifunctionality, biodiversity, ecomimicry, ecosystem services*

1. Introduction

One of the key strengths offered by urban green infrastructure (UGI) to city planners is its multifunctionality, being able to provide environmental, social and economic ecosystem service benefits (EC, 2012; SCU, 2012). If designed and sited appropriately, UGI can represent nature based solutions to interrelated issues associated with urbanisation that are relevant to all public authorities. This includes flooding, urban heat island, air quality, recycling, biodiversity and health & well-being of communities (Ahern, 2007; Tzoulas et al., 2007; Wolf, 2003). This paper proposes that, if a 'Renaturing of Cities' strategy is to maximise the ecosystem service provision of UGI (DGRI, 2015), then detailed consideration of a habitat services, biodiversity-led approach and multifunctionality are necessary rather than relying on the assumed biodiversity benefits of UGI *per se* (Simons et al., 2008). Loss of biodiversity due to urbanisation and the associated degradation of ecosystem services are predicted to impact the physical, psychological, and economic well-being of communities particularly in urban areas (MEA, 2005; Chapin et al., 2000; Pushpam, 2010). To reverse these trends, it is necessary not only to put back greenspace and nature in urban areas but to put back biodiverse, functioning ecosystems (Hostetler et al., 2011). Whilst this ecological approach to incorporating UGI is gaining traction in scientific and policy discourses, the application of the approach remains a key challenge to public authorities and developers because application-oriented frameworks in order to mainstream the approaches are still lacking (Hansen and Pauleit, 2014). Numerous barriers to the development of such frameworks are preventing implementation and up-scaling (Figure 1). Adoption of a 'learning-by-doing' approach based on science-practice collaboration and cross-disciplinary cooperation has been identified as a key component of unlocking these barriers (Ahern, 2011; Hansen and Pauleit, 2014).

Considering the city as a Social Ecological System (SES) provides a framework for understanding the interconnectedness of citizens, physical spaces and policies in a way that enables urban resilience and sustainability approaches to be developed (Vandergert et al, 2015). Emerging research suggests that a social-ecological approach can be promoted by multi-stakeholder experiments that bring together expertise from individuals, organizations, agencies and institutions at multiple organizational levels. The outcomes of these partnerships need ultimately to be translated into the planning/policy framework through adaptive governance processes (Folke et al, 2005; Wilkinson, 2012) in order to ensure that transformation opportunities are not missed. This paper shows how multifunctional ecosystem service benefits may be supported by nature-based solutions through a process of 'ecomimicry', for the design of biodiverse and regionally typical UGI. 'Ecomimicry' is the practice of designing socially responsive and environmental responsible technologies for a particular locale based upon the characteristics of animals, plants and ecosystems of that locale (Marshall, 2007).

This paper presents preliminary data from three case studies that explore how multifunctionality can be achieved, the stakeholders required, how an experimental approach is a useful tool for affecting transformation, how this can be fed back into policy, and how such a process can begin to address some of the barriers preventing broader application. Our research contributes to the emerging science/policy discourse that identifies a gap in knowledge about how to implement policies that contribute to multifunctional UGI and the positive benefits that can accrue at the local level to both people and ecosystems (Hostetler et al., 2011; Hansen and Pauleit, 2014; Nassauer and Raskin, 2014). Through practical experimentation and a multi-stakeholder approach, we aim to demonstrate to planners and developers the value of biodiversity-led design in ecological and social terms and how to incorporate the principles in both site-specific and strategic planning contexts at the local and regional level. Our work therefore contributes to conceptual research that takes a systems and strategic approach to designing and managing greenspace with specific reference to multiple spatial scales from metropolitan parks and naturalistic corridors to micro-green areas (Hansen and Pauleit, 2014; Shwartz et al., 2014). In particular, our research is focused on answering the key question being raised in the literature; that is how to implement a systems approach for creating and managing biodiverse UGI through strategically based local urban interventions. Linked to this we explore how best practice can be transferred between cities to build resilient and sustainable communities. Furthermore, we argue that incorporating locally contextualised biodiversity-led UGI design contributes to the functioning and resilience of the city. It does this by providing the adaptability to respond to locally contextualised challenges, such as overheating, flooding, air pollution, health and wellbeing as well as biodiversity loss.

The following section details a conceptual framework for UGI benefits and barriers to implementation and how this was used to underpin the research case studies. Section 3 presents preliminary data from the three case studies, outlining the specific challenge in each case, the implementation process, emerging results, and case study learning to address barriers. Section 4 presents overall results in relation to the conceptual framework, including key lessons learned, and we conclude by discussing further areas for research.

2. Method

Figure 1 represents a conceptual framework of the functional role that green infrastructure can play in an urban context. The framework was generated during the research phase of the FP7 TURAS project based on discussions with Local Authority planners. It is intended to illustrate the potential multifunctional benefits that can be attained through appropriately designed UGI juxtaposed against perceived barriers to implementation. In so doing, it frames our research to encompass both the science of biodiversity-led UGI and the co-development of methods for incorporating a strategic approach to implementation of biodiversity-led UGI by planners and developers. This is recognised as a gap in current knowledge (Hostetler et al., 2011; Hansen and Pauleit, 2014). The following case studies were selected to test this framework, and are an ongoing research area.

In order to illustrate new approaches in urban planning, it is often illuminating to draw inferences from case studies, something that has been shown many times (e.g. Ritzema et al., 2010; Sevenant and Antrop, 2010). The Barking Riverside Brownfield Landscaping, the Ludwigsburg Green Living Room and Derbyshire St Pocket Park case studies presented here were selected as examples of how biodiversity conservation and multifunctionality may be embedded into the heart of transformative strategic urban planning through a multi-stakeholder hands-on approach to delivering nature-led UGI. Each represents a novel approach to biodiversity-led UGI design incorporating multifunctionality. Each was selected to address different aspects of the conceptual framework and barriers to implementation. In three different contexts the case studies use targeted multifunctionality and 'ecomimicry' as an integral part of biodiversity-led design, together with a multi-stakeholder approach to planning and implementation. The case studies are contextualised by establishing the challenges, describing implementation of the concept (including targeted ecosystem service multifunctionality), presenting emerging results, and discussing in relation to case study learning to address barriers to broad implementation.

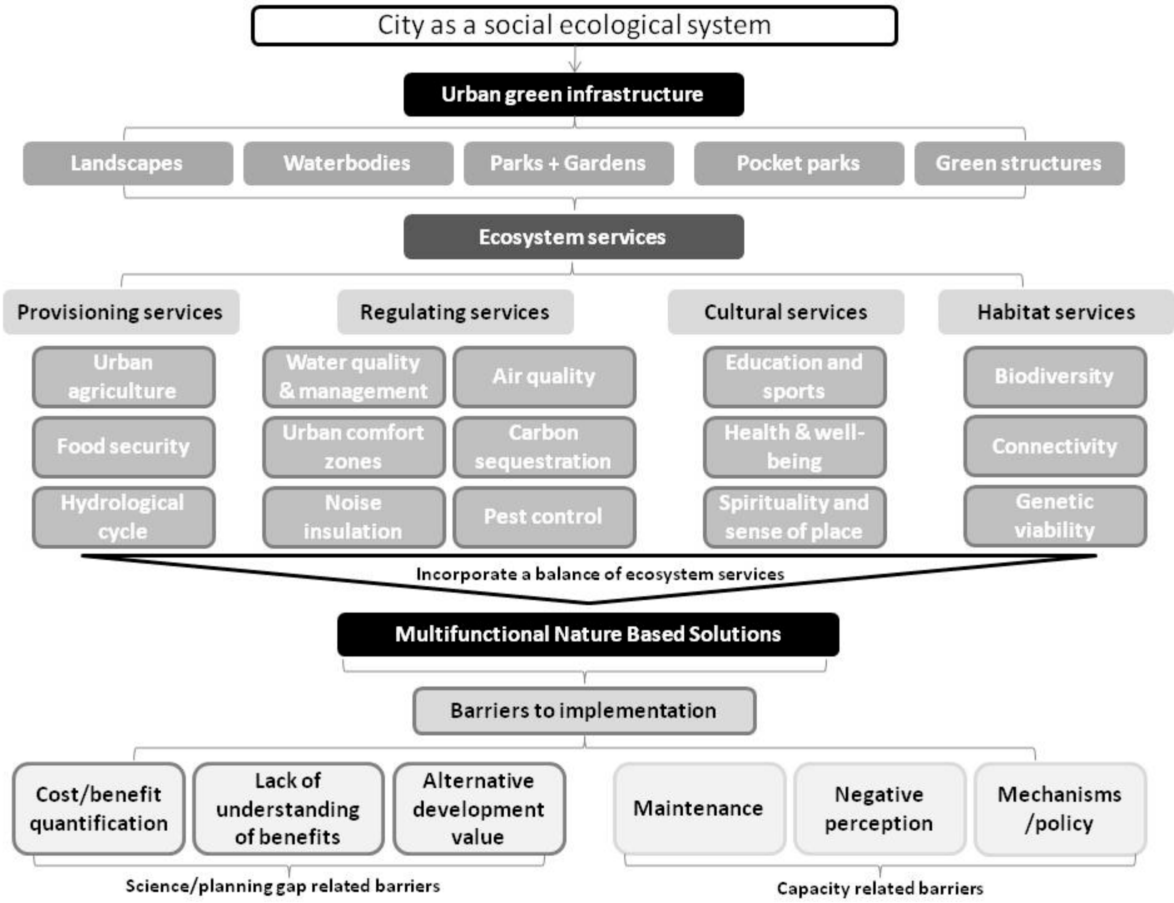


Figure 1. A framework of green infrastructure implementation in urban areas. The framework presents Green Infrastructure as typologies typical of the urban context linked to examples of associated ecosystem services that may be achieved in urban areas through appropriate multifunctional design of nature based solutions. Presentation of the potential benefits of Urban Green Infrastructure (UGI) are juxtaposed against identified barriers to implementation. In so doing, they present foci for research and innovation to support UGI development and maximise benefits.

3. Results

3.1 Barking Riverside Brownfield Landscaping

Challenge

Barking Riverside is a new community being developed beside the River Thames in the London Borough of Barking and Dagenham (UK). The site sits within the Thames Gateway, an area designated a national priority for urban regeneration and sustainable development.

Central to this designation was the number of brownfield (post-industrial) sites. Barking Riverside is being developed on one of these, a 180 hectare brownfield site in the south of the borough. Originally marshland, the site was drained and a coal-fired power station was built in the 1920s. Deindustrialisation of urban areas brought closure to the power station in the 1980s and the site remained unmanaged until purchased in 1994. Following planning consent, Barking Riverside Ltd, a public-private partnership, began a rolling programme of construction on the new development in 2010. Central to the planning consent was recognition of the semi-natural state of the brownfield site and the challenge of conserving the multifunctional ecosystem service values of the site within the new community. This included identifying the value of the site for greenspace access, stormwater storage and biodiversity.

In the UK a series of brownfield sites have been found to support nationally significant populations of numerous conservation priority invertebrates (Jones, 2007; Harvey, 2007). Typically comprising a blend of friable substrates and pockets of contamination, many of the Thames Gateway brownfield sites represent open flower-rich resources with no management intervention that lend themselves to supporting many warmth-loving species at the edge of their range (Harvey 2000). Such is the value of the habitat in otherwise heavily managed urban and rural landscapes that the habitat typical of the highest quality brownfield sites has been characterised and included in the list of UK Biodiversity Action Plan (BAP) priority habitats (Riding et al., 2010) as Open Mosaic Habitats on Previously Developed Land. Brownfield sites are under greatest pressure from Thames Gateway development (Harvey 2000) and the highest quality sites for biodiversity are disappearing at an unsustainable rate with over half lost between 2007 and 2013 (Robins and Henshall 2012). For development in the region to be sustainable, nationally important invertebrate populations must be protected through conservation and effective mitigation.

The value of these brownfield sites is in the complexity of microhabitats within the wider mosaic, which support species throughout their lifecycles (Bodsworth et al. 2005). Examples of these habitat requirements include the conservation priority species the 5-banded tailed digger wasp (*Cerceris quinquefasciata*) and the brown-banded carder bee (*Bombus humilis*). Both species require specific floral resources but also require very different nesting habitats, in the form of small patches of bare sandy ground and dense grass swards respectively, juxtaposed over appropriate spatial scales to the floral resources. Habitat typical of the highest quality wildlife-rich brownfield sites includes a mosaic of open flower-rich resources, seasonal wet areas, shelter belts of mid/late successional trees and bushes, early successional ruderal and scrub, south facing slopes, lichen and mosses, bare ground that heats up rapidly, and blends of friable substrates (Bodsworth et al. 2005; Buglife 2009; Riding et al. 2010). This habitat mosaic is something that should be aspired to through 'ecomimicry' in UGI design if biodiversity conservation is to be a goal in urban areas.

As part of the process of ensuring that sustainability was at the core of Barking Riverside design a Knowledge Transfer Partnership (KTP) was established to investigate how UGI design could be incorporated into masterplanning. The aims being to maximise biodiversity by continuing to support the species assemblages present on the brownfield site prior to development. Also, ensuring that sustainability and resilience were embedded at the heart of the new community by conserving the multifunctional ecosystem service provision of the brownfield site within the new development (e.g. stormwater amelioration, access to greenspace). The key first step was to ensure that UGI design was multifunctional and based on regional context, both in terms of being climate-resilient and relevant to regional biodiversity of national and international conservation importance. This was achieved through ecomimicry of the pre-development state of the site. The 'added value' of such a biodiversity-focused climate-resilient approach would be that the management requirements of the UGI become more sustainable with reduced requirements for fossil fuel use, artificial irrigation, and fertilizer and pesticide input. To achieve the aim of incorporating multifunctional biodiversity led UGI into the masterplanning of the new development required a multidisciplinary, multi-stakeholder experimental approach to landscape design and subsequent implementation into strategic planning.

Implementation

In knowledge co-creation, societal stakeholders and practitioners from various disciplines collaborate on solutions-orientated approaches to problems (Regeer and Bunders, 2009; Mauser et al, 2013). Such collaboration is vital to ensure that relevant practical knowledge is applied through a joint learning process to achieve multi-beneficial resolutions to societal and ecological problems. Examples include bringing together UGI design for amenity use, urban landscape design, and design for biodiversity. For multifunctionality to be incorporated into UGI design and the legacy of such UGI to be secured, it is vital that co-creation processes are used. At Barking Riverside the KTP comprised the key stakeholders necessary for co-creation of knowledge and implementation of best practice into the masterplanning process and local strategic planning. This included design and management meetings involving the developer, the local authority, ecologists, landscape architects, and the public body of the government responsible for the natural environment. Community engagement has also been central for ensuring the success of the Barking Riverside development (Healey, 2006; Lane and McDonald, 2005). Engagement has been carried out through consultation with residents to assess their needs for greenspace (from amenity to wildlife). For biodiversity-led landscaping initiatives at the site, engagement has comprised introducing residents to the biodiversity value of the pre-development state of the site, and the habitat design and management necessary to conserve the wildlife and associated ecosystem services. This is vital to overcome negative perception over UGI design for biodiversity and to promote the legacy of the UGI as, ultimately, it will be a Community Interest Company made up of residents that will take over management of the Barking Riverside greenspace.

It has been recognised that biomimicry (Benyus, 2002) is central to the design of UGI in order to restore ecosystem services in urban areas (Lundholm, 2006; Grant, 2012). This case study took this concept forward by demonstrating two key aspects. Firstly, that it is necessary and possible to incorporate 'ecomimicry' of substrates, plant diversity and habitat structure typical of regional habitat of local, national or international conservation value in order to achieve biodiverse and multifunctional UGI with low management requirements. Secondly, that it is possible to meet development mitigation targets in terms of conserving the wildlife associated with the pre-development state of the site. When brownfield sites are redeveloped following traditional urban landscape design principles, many of the vital synusia (niche-specific features) (Gillet & Gallandet, 1996) that support broad biodiversity are lost. At Barking Riverside several ground-level and roof-level UGI initiatives were instigated by the KTP to investigate the potential for supporting the biodiversity associated with the brownfield. One of these comprised incorporating the synusial habitat features characteristic of the region's brownfield sites into traditional office landscaping design techniques This was done to assess whether it was possible to create biodiversity-focused UGI using traditional landscape design principles within residential and commercial areas. In order to establish an experiment to assess the potential of such 'ecomimicry', a series of habitat pockets covering an area of approximately 0.5 ha were created containing traditional urban landscaping features (e.g. ornamental flower beds, evergreen hedging) blended with brownfield habitat features (e.g. south facing sand banks, metal and concrete features, scrub bands and standing deadwood). The landscaping was designed in such a way as to target ecosystem service multifunctionality (Figure 2).

Ecosystem service	Targeted provision at Barking Riverside case study
Habitat	Biodiversity
Habitat	Connectivity
Cultural	Sense of place
Cultural	Amenity space
Cultural	Education
Regulating	Urban comfort zone
Regulating	Stormwater management

Figure 2. Targeted ecosystem service multifunctionality at Barking Riverside case study

LINK TO PHOTOS OF CASE STUDY INSERTED HERE IF NECESSARY AND LINK TO SITE PLAN IN APPENDICES

Emerging results

148 species of higher plant were recorded on just 0.5 ha of urban landscaping with significantly greater floral diversity on brownfield landscaping areas than on surrounding soft landscaped areas. Many of the floral species recorded were considered to be indicative of the high quality brownfield habitats within the region (Roberts et al., 2006). Invertebrate species recorded included species of national conservation concern, most notably two UKBAP bumblebee species, and Red Data Book 1 and RDB2 species, several nationally rare and scarce species as well as numerous Essex RDB species. The brownfield landscaping consistently outperformed soft landscaping areas in terms of overall invertebrate diversity and for specific target indicator group (Aranaea, Coleoptera and Hymenoptera) numbers, diversity and conservation importance. In addition, timed observational surveys and pitfall trapping revealed variation across the landscaping relative to habitat heterogeneity. This indicated that the mosaic of habitats created within the landscaping may have been enhancing overall site biodiversity.

Case study learning in relation to UGI barriers

Lack of understanding of benefits - emerging results indicated that using ecomimicry of regionally typical habitat of local or national importance to design UGI can be an effective tool for supporting biodiversity objectives. Moreover, such design would be expected to provide at least as broad an array of additional ecosystem services benefits as generic urban soft landscaping. Whilst this has yet to be studied for ground-level habitat, results emerging from TURAS have indicated that roof-level green infrastructure designed using ecomimicry can perform as well as, or outperform, industry standard generic green roof systems for ecosystem services (Connop et al. 2013). This includes water attenuation and thermal insulation in addition to enhancing overall biodiversity.

Cost-benefit quantification - involvement of multiple stakeholders in the project development combined with monitoring of benefits has enabled a cost/added-value quantification to be carried out on the project. This is now being used to inform other brownfield landscaping projects and development mitigation guidance.

Negative perception - steps to overcome negative perceptions included working with landscape architects to create and demonstrate landscaping that combined ecological functionality with the aesthetic principles of urban landscape design.

3.2 Green Living Room

Challenge

Conurbations and more specifically their city centres have a huge impact on local climatic conditions (Goward, 1981). Due to a high percentage of sealed surfaces and lack of greenspace the average temperature in cities is higher than in the surrounding rural areas resulting in the urban heat island effect (UHIE) as one aspect that characterizes the urban climate. Climate change will exacerbate this effect (McCarthy et al., 2010; EEA, 2012). Urban and landscape planning concepts can deal with challenges related to urban climate in general and UHIE in particular. There is also a rich architectural tradition of how to deal with the problem on a fine scale in order to create liveable urban environments and enjoyable open spaces. The Urban Climate Comfort Zones (UCCZ) concept brings together these fields of expertise and introduces two new types of plan: UCCZ development plan and UCCZ action plan (Figure 2). With a focus on the ‘attractiveness of open spaces’, the UCCZ concept is considered a good starting point for more elaborate planning guidelines and, potentially of more importance, discussions with the public about appropriate responses to climate change. Local adaptation measures proposed in the action plan for specific sites range from architectural interventions (e.g. retractable umbrellas) to nature based solutions for targeted ecosystem service provision (e.g. green roofs). The Green Living Room (GLR) project in Ludwigsburg, Germany, can be seen within that scope, providing an example of a new hybrid type of project. It was designed to tackle the challenges posed by the UHIE and also to deliver multifunctional ecosystem services related to biodiversity, amenity value, stormwater management and noise reduction.

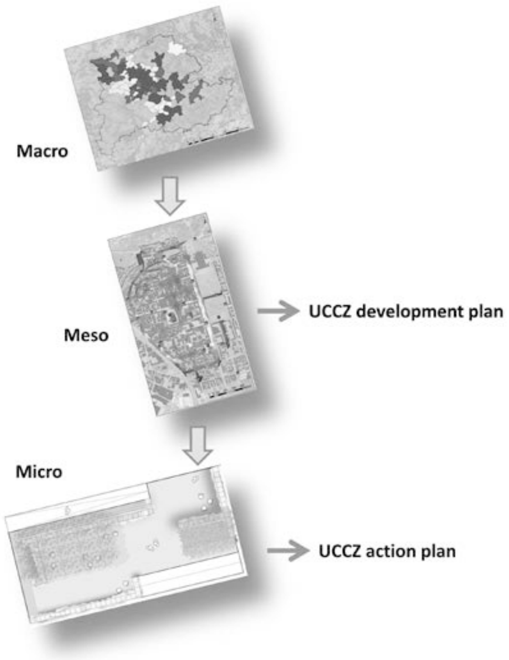


Figure 3: General approach of the UCCZ-Concept (Eisenberg et al., 2015). A screening process to macro/regional level leads to the selection of municipalities in need of a

development plan. The specific adaptation measures are specified in the detailed UCCZ action plan.

Implementation

Vulnerability analysis for the Stuttgart region has identified risks to the population due to increased temperature, including municipalities with a high proportion of vulnerable inhabitants (Weis et al., 2011). This risk is predicted to increase with a doubling of the days with 'bioclimatic heat stress' on communities forecast for the period 2070 to 2100. As a consequence of this, the area at risk within the region would increase from 5% to 57% (VRS 2008). In order to combat this, the region is investigating climate adaptation strategies. As part of this programme, the GLR was established as a competition for towns in the Verband Region Stuttgart, Germany. Following lengthy negotiations, it was agreed that the GLR would be established on the “Rathausplatz”, an area above an underground car park near the Ludwigsburg town hall. The project idea met the 'greenery in the city' objective that was developed previously during an intensive public participation and collaborative planning process called Future Conferences. The GLR was inaugurated in April 2014. It combined, for the first time, the modular wire-cube structure (WABA-modules) for living walls with living plant constructions in a highly urban area. The novel free-standing green wall structure consisted of pre-cultivated modules. Such a system is ideal for application in urban areas due to the small area required and huge variety of designs possible. This approach enabled a new type of UGI module to be established providing 3D urban greenspace capable of providing multifunctional ecosystem services. The high level of flexibility and adaptability of the modular system together with the techniques of pre-cultivation and living plant construction enabled faster development of the vegetation than conventional planting (Ludwig et al., 2015). This led to a “mature” performance in terms of vegetation-based ecosystem services, such as mitigating the UHIE, filtering air pollutants and provision of habitat, within much shorter timeframes. It also enables small green oasis solutions to be developed even in difficult locations.

The selection of plants for the green wall elements was informed by four considerations: positive influence on local biodiversity; robustness of plants for the special habitat of a living wall; improving amenity value qualities (shade and shelter); aesthetic and sensory aspects. The completed GLR contained 6976 plants and 128 plane trees and enriched the Rathausplatz with ~140 m^2 of vertical vegetation. In addition, the roof of the plane trees (the most effective species for the plant addition method) created a shaded area of ~40 m² immediately after installation (Eisenberg et al., 2015). Despite its main function as a local mitigation measure against heat stress, the design of the modular system ensured that the GLR provided multifunctional benefits (Figure 4). This included stormwater management benefits (rainwater harvesting for irrigation), air quality improvements (fine dust), noise reduction (DIN EN 1793 group 3), biodiversity (including locally important groups such as pollinators), and creating an open greenspace with high amenity value for health and well-being.

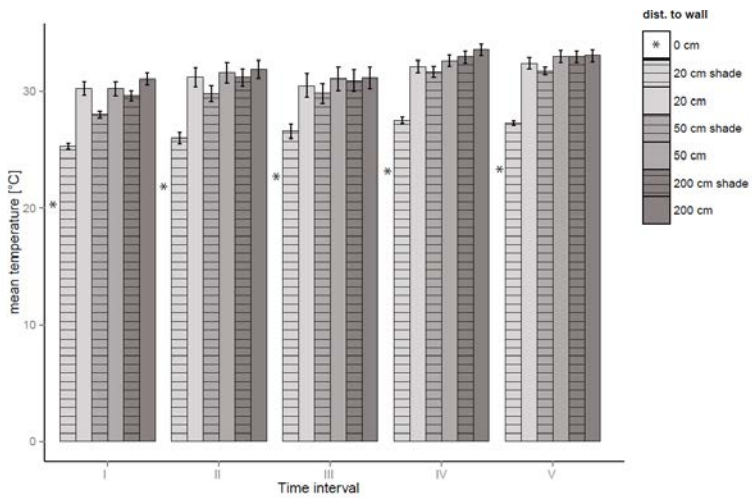
Ecosystem service	Targeted provision at Ludwigsburg case study
Regulating	Urban comfort zone
Regulating	Noise insulation
Regulating	Air quality
Cultural	Sense of place
Cultural	Amenity space
Cultural	Health and wellbeing
Habitat	Biodiversity
Habitat	Connectivity

Figure 4. Targeted ecosystem service multifunctionality at the Ludwigsburg case study

LINK TO PHOTOS OF CASE STUDY INSERTED HERE IF NECESSARY AND LINK TO SITE PLAN IN APPENDICES

Emerging results

From the outset the GLR attracted many visitors. Despite being early in the development process, the efficiency control that was performed for the GLR was solid and well-considered providing first insights into the performance of the novel structure and the level of acceptance by Ludwigsburg's community. This included measuring the effect of the GLR as a local mitigation measure that improves the amenity value within the UCCZ Development Area in Ludwigsburg. To investigate the effect on the microclimatic conditions, a series of measurements of environmental parameters were conducted (Eisenberg et al., 2015). The aim was to explore the performance of the GLR as a cooling and shading facility during days with high air temperatures and to measure effects on adjacent areas. Initial results have been very promising. Measurements of air temperature and relative humidity around the two wall compartments of the south side indicated that there was a cooling effect of the wall. This cooling effect was evident in the mean air temperature and relative humidity values measured across a gradient of positions (Figure 5). Emerging results demonstrated that mean air temperature was lowest and relative humidity was highest at shorter distances ≤50cm for both wall compartments. In addition, a difference between the two wall compartments was found. The mean air temperature reached higher values for the wall compartment with direct sun-radiation and mean air temperature was lower for the wall compartment with plant vegetation shaded by the plane trees. Measurements showed that mean air temperature was always less and relative humidity higher at the shaded wall compartment for the same day-time periods (Figure 5). Plant coverage, irrigation, noise insulation, biodiversity, and open space evaluation are also being monitored with encouraging results (Eisenberg et al., 2015).



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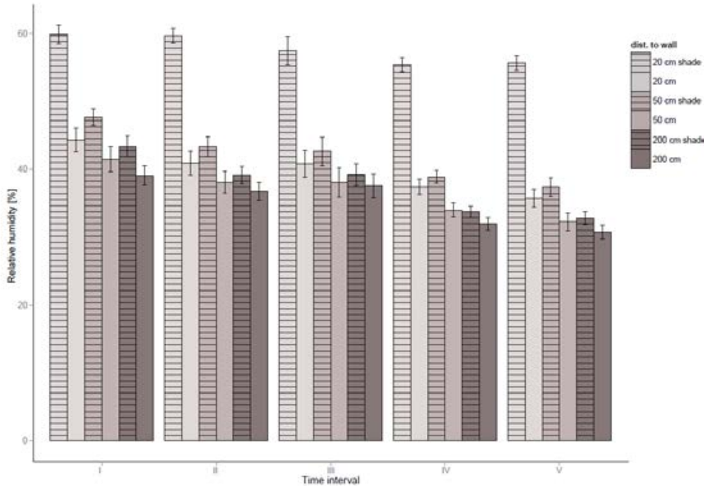

ii)

Figure 5: i) The mean temperatures and ii) the mean relative humidity values measured at the shadowed and un-shadowed sites of the Green Living Room during different time of the day. The time periods were: (I) 10:15-11:00 (II) 11:15-12:00 (III) 13:15-14:00 and (IV) 14:00-15:00.

Case study learning in relation to UGI barriers

Mechanisms/policy - due to its multifunctionality and adaptability, the GLR concept can be used for many different purposes and contexts. As a "UGI module" it could serve primarily as a constructed habitat for plants and animals, water retention structure, noise barrier, green open space installation, or mitigation measure that not only enhances the microclimate of a 'living room' space but of a whole city block. The advantage of the WABA wire cubes is that they can be covered with vegetation on one side or both sides, resulting in standalone (like the GLR) or façade-like structures. They could also be suitable for a series of small functional urban buildings, (e.g. bus stops, kiosks, grit storage). Furthermore, because the walls rest on a simple strip foundation, the modules can be erected on rooftops, underground buildings and other difficult locations without the need for physical connection underground.

Adaptation to climate change is an issue in urban and landscape planning, however the formal planning system does not yet promote experimental adaptation measures. With a demonstrably successful GLR project, this showcase for local adaptation measures could become part of "climate proofing schemes" in urban and open space planning. The potential of the project is that it contributes to urban resilience by demonstrating that sophisticated living wall systems can play vital roles in creating and connecting greenspace in cities for multiple ecosystem services. This includes heat island mitigation, stormwater retention, defragmentation (biodiversity links) and amenity value. The project also fits into the city development concept. This is part of the collaboratively elaborated sustainability strategy of Ludwigsburg, because it relates to the central topics of 'greenery in inner city' and 'lively city centre', and the aims of implementing more adaptation measures into the formal planning system. With these measures, resilience in the sense of heat stress-resistance would be increased, helping to raise awareness of relevance for long-term planning.

Lack of understanding of benefits - the comprehensive monitoring programme is also providing data on the multifunctional benefits provided by a 'Green Living Room'. This includes the benefits of the immediately functioning canopy in providing shade and cooling compared to more traditional methods where much longer periods of growth are required to achieve such benefits.

Cost/benefit quantification & Maintenance - the involvement of the SME pioneering this approach to 3D UGI design, Helix Pflanzen GmbH, as a stakeholder in the monitoring programme has also enabled comprehensive data on the cost/benefits, the maintenance requirements of such an approach, and the potential for a 100% rain-fed irrigation system to be catalogued and disseminated.

2.3 Derbyshire St Pocket Park, Bethnal Green, London

Challenge

Global warming-induced climate change is predicted to cause an increase in the frequency and intensity of rainfall events (Department of the Environment, 1996; UKCIP, 2001; Meehl et al., 2007). This brings new challenges for fluvial and pluvial stormwater management. The EU Floods Directive (2008) was introduced to support member states in addressing these challenges by requiring them to develop and update a series of tools for managing all sources of flood risk. In England and Wales, the Directive was transposed through the Flood Risk Regulations (2009) and subsequently through the Flood and Water Management Act (FWMA) (2010) and in the National Planning Policy Framework. Included within the FWMA is definition of the role of lead local flood authority (LLFA) to develop, maintain, apply and monitor a strategy for local flood risk management in its area. This includes responsibility for the approval of sustainable drainage designs for all major planning applications. In London, the relevant borough is the Local Planning Authority and the LLFA (Mayor of London, 2015).

In urban areas, old and new technologies are being combined to generate Sustainable Urban Drainage Systems (SUDS) and Water Sensitive Urban Design (Lloyd et al., 2002) in order to mitigate stormwater runoff and reduce the occurrence of flooding. LLFAs represent a mechanism by which UGI solutions can be prioritised to ensure that SUDS benefits are multifunctional and provide broad ecosystems services (Mitchell et al., 2006; Grant, 2012). LLFAs also provide an opportunity to ensure that systems are designed for regional context including providing opportunities to support national, regional or local biodiversity targets. In order to investigate the potential for such action, TURAS researchers worked with the London Borough of Tower Hamlets (LBTH) to develop a planning policy guidance note that would apply regionally contextualised 'ecomimicry' UGI design principles into SUDS component design. Key challenges were to ensure that SUDS design recommendations focused on those suitable for high-density urban areas and that supporting biodiversity and additional ecosystem services were central to the design and selection of components.

Implementation

The guidance produced (LBTH, 2015) represents an exemplar of how cross-disciplinary local authority urban planning and engagement with external partners can promote multifunctional benefits from urban planning initiatives and how legislative requirement such as SUDS can provide leverage to achieve real biodiversity benefits through renaturing urban areas. The SUDS guidance initiative was led by the LBTH Highways and Environment planning teams in partnership with ecologists with local expertise. In order to showcase the collaborative development of SUDS guidance and the multifunctionality that can be achieved through incorporation of 'ecomimicry' into UGI design principles for urban SUDS, LBTH applied for the Mayor Of London's Pocket Park funding to develop a flagship for their SUDS initiative. Realisation of the designs through a Pocket Park was supported by a private partnership including landscape architects, a water company, a community and arts centre, and a small-scale green roof construction company. The Pocket Park showcases a selection of the SUDS solutions incorporated into the guidance and demonstrates how they could be incorporated together. The solutions showcased were: rain gardens (planted with native and regionally typical species of benefit to pollinators), attenuating planters (planted with herbs for local residents to use), small-scale green roofs (utilising opportunities such as bike shelters and bin covers to incorporate green roofs with native and regionally typical planting to maximise benefits for conservation priority insects and urban birds), swales (to convey runoff to various SUDS components), and permeable surfaces (to maximise infiltration). Planting lists for the guidance and Pocket Park were developed based on regionally typical species, species targeted in local Biodiversity Action Plans, and species known to perform well in urban green roofs, rain gardens and tree pits. A focus on green solutions ensured the park would provide a range of additional ecosystem service benefits (Figure 6).

The Derbyshire Street area of Bethnal Green, London was identified as a suitable location for this initiative as, despite the surrounding urban spaces being a hive of activity, the dead-end of the street itself was an area blighted by fly-tipping and anti-social behaviour. The presence of a community and arts centre on the street also represented an opportunity for consultation in relation to providing for social benefits. Following its launch, the park stands as a showcase of how regional context and community assets can be fed into SUDS component design and selection in high density urban areas to promote transformation to greater resilience and sustainability. It also stands as a demonstration for developers in LBTH of how to include the guidance-recommended multifunctional SUDS components into future developments and retrofits.

In addition to being a SUDS showcase, this innovative use of an underused space provides the local community with numerous added benefits. This includes providing a relaxing social environment, space for cafe tables and chairs, covered bike racks at a key stopping point along a cycle route, edible planters containing herbs for local residents, a space for small-scale workshops and events, and an enhanced pedestrian realm.

Ecosystem service	Targeted provision at Derbyshire St case study
Regulating	Urban comfort zone
Regulating	Water quality and management
Cultural	Sense of place
Cultural	Education and sport
Cultural	Amenity space
Cultural	Education
Habitat	Biodiversity
Habitat	Connectivity
Provisioning	Urban Agriculture

Figure 6. Targeted ecosystem service multifunctionality at Ludwigsburg case study

LINK TO PHOTOS OF CASE STUDY INSERTED HERE IF NECESSARY AND LINK TO SITE PLAN IN APPENDICES

Emerging results

Whilst there is currently no scope to monitor SUDS performance of the Derbyshire St Pocket Park initiative, public perception of the space has been very positive, with the space being used for several social events. Moreover, a biodiverse haven has been created in a very urban borough. In the absence of detailed monitoring, key results from the project comprise learning from the processes behind the achievement, demonstration of how SUDS can be used to leverage additional ecosystem services, and how regional context can be incorporated into industrial standard SUDS component designs. It is hoped that the principles behind the demonstration will be rolled out on a large urban scale, including an additional precursor step of ecosystem service analysis (Pedersen Zari, 2014) where SUDS designs are tailored for local environmental problems and community needs.

The hope now is that the SUDS guidance document and Pocket Park will inspire a host of multifunctional benefit SUDS initiatives from small to large scale within Tower Hamlets and beyond, with particular focus on delivering biodiversity benefits to urban areas deficient in access to greenspace.

Case study learning in relation to UGI barriers

Mechanisms/policy - Derbyshire Street Pocket Park represents an exemplar of partnership stakeholder working to maximise the multifunctional benefits of UGI retrofit opportunities such as SUDS. This initiative is now being used by TURAS, CIRIA (Construction Industry Research and Information Association) and the Greater London Authority's Drain London programme (Mayor of London 2015) as a case study to raise awareness across London and other major cities globally about the potential added value benefits that can be achieved through SUDS. In particular, the biodiversity benefits that can be achieved by applying 'ecomimicry' of regionally important habitat into UGI design. By documenting the co-creational processes involved in delivering this initiative within TURAS it is hoped that a blueprint for transformation can be provided to other local and regional authorities.

Maintenance - practical implementation of this biodiversity-led SUDS initiative is also providing data on the maintenance requirements for such systems.

Negative perception - incorporation of UGI SUDS solutions into the creation of a pocket park social space in an area that was previously blighted by fly-tipping and anti-social behaviour has helped reverse negative perceptions associated with UGI retrofit.

4. Link between empirical findings and conceptual framework

The conceptual framework outlined in Figure 1 presents UGI within the context of the city as a social-ecological system, indicating the complexity and interconnectedness between people, places, ecosystem services and implementation policies. Whilst this complexity provides a challenging framework for analysis, the SES approach to urban planning offers opportunities to develop urban resilience and sustainability strategies (Vandergert et al., 2015) and to explore UGI multifunctionality. We have used the case study approach to analyse this in order to provide an appropriate methodology to blend science and policy in action at different urban scales, from local to regional.

Case studies have been used to explore the policy implications of numerous urban issues such as stakeholder reaction to UGI proposals (Baptiste et al., 2015), urban parks and their use (Baur et al., 2013), urban heat effects (Oliveira et al., 2011), and new approaches to urban policy (Shandas et al., 2008). The case studies presented here are intended to begin to move beyond a scientific and technical focus to incorporate knowledge exchange and collaboration with key stakeholders so that a strategic and applied approach to incorporating UGI as an integral part of city planning can be implemented. The lack of knowledge about how to embed emerging urban ecological science within urban policies and planning practice is a key challenge for scientists and remains a barrier for widespread implementation (Hansen and Pauleit, 2014). Chosen as part of the FP7 TURAS project, these case studies demonstrate how design for biodiversity (including 'ecomimicry') can play an important role in optimising the multifunctionality of UGI, how multi-stakeholder partnerships can work in the design, planning and implementation of UGI through adaptive governance, and how such case studies can begin to address barriers to UGI implementation (Figure 7):

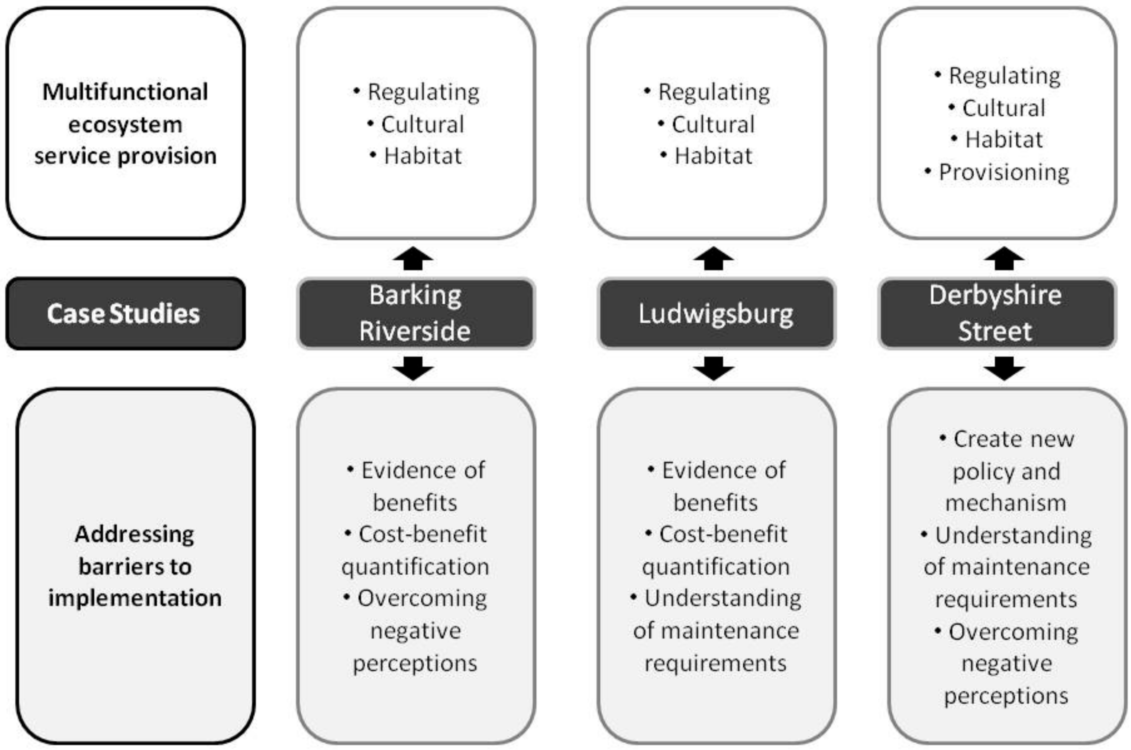

Figure 7. The case studies and their relationship to the conceptual framework.

Barking Riverside

This case study provides practical pointers as to how a new and very diverse community can be established whilst retaining and supporting the valuable biodiversity and ecosystem services associated with a development site through sustainable and resilient biodiverse UGI planning and design. In so doing, the case study addresses perceived barriers to UGI implementation including: lack of understanding of benefits; cost-benefit quantification; negative perception. Using a multistakeholder approach to achieve this enables these barriers to be addressed more effectively, including an economic model for long-term management. The case study thus provides evidence to enable the potential for up-scaling of such initiatives more widely.

In order to enhance this benefit, continued monitoring of the landscaping is vital to develop additional learning. This includes establishing the appropriate management for novel landscaping, the costs associated with such management compared to traditional landscaping techniques, and monitoring patterns of biodiversity on the landscaping as the Barking Riverside brownfield site as a whole continues to be developed. It is also important to quantify the additional ecosystems service benefits of an ecomimicry approach to biodiverse UGI in relation to more engineered or single-service targeted solutions. Nevertheless, this landscape design experiment can act as a blueprint for targeted biodiversity conservation in urban development projects. Research from the Barking Riverside case study is already being used in Local Authority planning guidance and site masterplanning, with opportunities to produce developer protocols in development phasing.

Green Living Room

The Urban Climate Comfort Zones approach represents geo-data analysis as a scoping mechanism to ensure that UGI installations are targeted to areas where they can provide the most benefit with the least competition/trade-offs. By adopting such an approach it is possible to maximise the cost/benefits and ensure that benefits are targeted for communities most in need. Combining this approach with the flexibility and fluidity of the WABA GLR components enables multifunctional ecosystem service provision to be adaptable and location-specific. The partnership of local authority, academic institution and designer/installer within the case study provided a platform for comprehensive data generation on monitoring and maintenance. The partnership also provided a pathway for these results to be fed directly back into planning and policy by addressing barriers to uptake. A direct example of this in Ludwigsburg is that the successful implementation of the GLR is now being incorporated within the regional climate adaptation strategy.

Derbyshire St Pocket Park

In Tower Hamlets, the Pocket Park now stands as an exemplar to demonstrate the practicability of the new borough SUDS guidance to public and private developers. Perhaps of even greater importance, however, is the demonstration of how mechanisms like SUDS can represent opportunities to leverage UGI retrofit in urban areas, and how inter-departmental and interdisciplinary collaboration is necessary to ensure that multifunctionality is embedded at the heart of such opportunities. By adopting this approach, it was possible to unite the aims and objectives of drainage engineers, highways planners, ecologists, and place-makers under a single initiative. In so doing, the case study began to address mechanisms/policy barriers preventing rollout and up-scaling of UGI through the planning process. Demonstration of the SUDS guidance through the Pocket Park also supported greater understanding of the maintenance requirements of such initiatives and targeted the reversal of negative perceptions associated with UGI SUDS solutions.

5. Discussion

In this paper we address some of the challenges faced in implementing UGI. The range and regional variety of biodiversity that urban areas have the potential to support has already been recognised (Secretariat of the Convention on Biological Diversity, 2012), and a need for a biodiversity-led approach to urban planning has been identified through the Convention on Biological Diversity (CBD) and ICLEI (Local Governments for Sustainability). All too often, however, single/narrow solution-based UGI designs for urban challenges rely on assumed benefits (Simmons et al. 2008; Connop et al., 2013) particularly in relation to biodiversity. By incorporating habitat services as a key component of UGI design we argue it is possible to achieve real biodiversity benefits and also enhance the range of ecosystem service benefits for communities. It has been argued that it may be difficult to recreate habitats that previously existed in urban areas and, thus, effort should be made to provide habitat for native species that may be more analogous to urban environments (Lundholm and Richardson, 2010). However, these case studies demonstrate that these ideas do not have to be mutually exclusive and regional context can be incorporated into local and regional UGI policy and planning.

The case studies presented represent practicable and transferable examples demonstrating how regionally-contextualised biodiversity-led UGI design does not preclude multifunctionality in terms of broad ecosystem service provision. Indeed, if adopted in tandem with an ecosystem services analysis approach (Pedersen Zari 2014; 2015) so that interventions are site specific and targeted to areas most at need (e.g. UCCZ approach), biodiversity-led design can provide a platform for nature based solutions providing environmental, social and economic benefits in urban areas.

Learning outputs from the TURAS case study experiences can support the broader establishment of such 'win-win-win' UGI outcomes. These learning outputs can be categorised into a series of key targets relating to the conceptual framework (Figure 8).

Learning outputs relating to the conceptual framework
Location-specific scoping mechanisms such as UCCZ analysis, biodiversity assemblage analysis and ecosystem service analysis are an important initial process to secure multifunctional locally-contextualised UGI solutions. Such scoping methodologies can support the development of strategies to prioritise actions, identify necessary stakeholders, address conflicts and trade-offs and maximise cost/benefits of UGI interventions
Co-development incorporating multidisciplinary stakeholders, including local communities, is central to capturing and embedding multifunctionality and bridging ecological and social needs analysis. This includes securing the legacy of, and engagement with, UGI and development of socio-economic models for the long-term management of the UGI
Demonstration, documentation and dissemination of the processes to achieve multifunctional UGI can remove some of the perceived barriers to broader implementation
Using practical experimentation in real-world case studies to monitor and quantify ecosystem service provision can support the development of guidance and policy ensuring transferability and potential for up-scaling of biodiversity-led solutions

Figure 8. Key learning outputs from TURAS case studies.

The next step is to develop upon these technical and policy findings to develop practicable UGI support tools that demonstrate how ecomimicry may be used as a design approach that can be directly incorporated into planning, at local and regional scales (from pocket parks to landscape ecological networks), for a more resilient social-ecological systems approach to urban planning. Physical planning techniques for shaping the greenspace within cities and meeting targeted living standards for inhabitants are traditional tools already in use by planners for city and neighbourhood planning. UGI introduces a new paradigm in relation to this urban greenspace planning (Hostetler et al, 2011). Of significant importance for applicability is being able to demonstrate these benefits to planners and policymakers in order to mainstream the approach; this remains a challenge, particularly in times of austerity and reduced public finances.

This innovative approach recognises the contribution that UGI may make directly to greenspace provision. It also goes further than this in recognising its value as a new city system component capable of supporting multifunctional benefits for the environment, biodiversity and communities and requiring multidisciplinary collaboration between environmental and social planning departments (such as energy, air quality, biodiversity, health & well-being) to ensure that multifunctional benefits are maximised. Early results identified two further challenges in relation to cities incorporating context-appropriate multifunctional biodiversity-led UGI: the policy/science interface, particularly in relation to capturing multifunctionality in design; and capacity and skills for planning, delivery and maintenance. These two challenges each combine design and governance perspectives. Notwithstanding the scientific goal of demonstrating how biodiversity-led UGI can deliver multiple environmental and health benefits, we have found that it can be difficult to create awareness among politicians and other stakeholders, especially when concrete results from planning and environmental experiments are not immediately evident. With reference to this issue, our research has attempted to demonstrate experimental results in real-world settings with outputs representing quantifiable benefits that are relatable to all Public Authorities and stakeholders. However, this requires a robust methodology for analysing UGI costs and benefits specific to place; a coherent regional/local approach to strategic as well as development planning; an understanding of regional context in terms of habitat design; and resources and skills to manage and maintain UGI assets so they contribute effectively to sustainable future cities. Our initial results suggest that an experimental multi-stakeholder approach to UGI can present opportunities to address some of these challenges.

As part of the process of addressing these key challenges, it is also necessary to consider management and maintenance of innovative UGI exemplars. Researchers are working with local authorities and communities to develop the social enterprise model to investigate the scope for UGI management and maintenance within a neighbourhood with a view to building local capacity for the technical, managerial and business skills to future-proof the UGI asset for local resilience (Crowe et al. submitted to special edition). These local initiatives have the potential to address a further research gap identified by Hostetler et al. (2011); that is how to facilitate education of developers and residents to embrace innovation in design and management of UGI and to increase wider understanding of environmental services and what they offer for improved health and wellbeing.

Our research to date has begun to demonstrate how innovative nature-based UGI solutions to building ecological and social resilience can be demonstrated and strategically incorporated within cities through planning policy development. Because our work deals concretely with the science/policy interface, we explore the implications for transferability and meeting the policy and planning challenges of future cities and the transformations required to build urban sustainability and resilience. The next phase of research is to work with multiple stakeholders to produce practical tools that incorporate the learning outcomes from TURAS to aid planners and developers embed biodiversity-led design in specific site contexts and through a more strategic systems-based approach to UGI delivery. Further analysis of the full suite of research tasks undertaken should provide a blueprint for how adaptive governance can ensure policy and planning mechanisms take account of ecomimicry in UGI design within both the strategic and local planning contexts.

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