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Developing a complementary framework for urban ecology

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ABSTRACT

Cities are characterized by dynamic interactions between socio-economic and biophysical forces. Currently more than half of the global population reside in cities which influence the global biogeochemical cycles and climate change, substantially exacerbating pressures on urban pollution, water quality and food security, as well as operating costs for infrastructure development. Goods and services such as aesthetic values, water purification, nutrient recycling, and biological diversity, that urban ecosystems generate for the society, are critical to sustain. Urban planners are increasingly facing the considerable challenges of management issues for urban ecosystems. Poor understanding of the complementary roles of urban ecology in urban infrastructure, and the functioning of ecosystems and ecological resilience of a complex human-dominated landscape has impeded effective urban planning over time, resulting in social disharmony. Here a complementary framework for urban ecology is proposed, in which ecosystems interact with land use, architecture and urban design – "E-LAUD" – affecting ecosystem and human health, and building on the concept that land uses in urban green areas, road-strips, wetlands, 'habitat islands' and urban architecture could synergistically benefit when clustered together in different combinations of urban landscapes. It is proposed that incorporation of the E-LAUD framework in urban planning forms the context of a new interdisciplinary research programme on ecological resilience for urban ecosystems and helps promote ecosystem services.

Introduction

Cities are an increasingly complex spectrum of human-dominated architectural infrastructures and ecosystems comprising green patches and wetlands (Bolund and Hunhammar, 1999). Currently as much as 50% of the global population live in cities (Grimm et al., 2008). High population growth rates and population increases are predicted from 7 billion today to 9.3 billion by 2050 and 10.1 billion by 2100 (Lee, 2011). Urban areas are expected to expand rapidly, leading to more than 60% of global populations living in cities by 2030 (Lee, 2011). Humans, at the centre of structural phenomena, modulate urban ecosystems for a range of services including food, energy, water and waste recycling (Carpenter and Folke, 2006). By doing so humans also profoundly alter species richness, composition and diversity through fragmenting habitats, introducing exotic species and changing land use and land cover patterns (Williams et al., 2009). Hough (2004) explicitly describes the relationship between cities and natural processes. Alternative values, such as attitudes and cultures based on ecological insights, may offer tremendous possibilities of constructive relationships between nature and humans. Urban designs may invite conflicts as they potentially risk affecting natural processes, while conversely the exploration of creativity and opportunities offer potential avenues to sustainable cities (Hough, 2004). In this regard, Waldheim (2006) further brings an excellent discourse on landscape urbanism, which describes urban environment as a disciplinary realignment within natural and architectural landscapes. This concept has revolutionized the narrow view of the classical urbanism, where a city was regarded as an architectural design in a condensed space encompassing the buildings, outdoor public spaces, and streets. Today, landscape is emerging as a model for urbanism, activating space and time, and leading to superior urban spaces as desired by society. Landscape urbanism is thought to be layered in a way that should reflect non-hierarchical, flexible, and strategic elements that are essential for design. Waldheim (2006) argues that by integrating landscape urbanism with design, the area in which the city resides greatly benefits the people who are using it. However, there are issues interfering with the concept of promoting landscape urbanism. In Australia alone, for example, more than 1700 species and ecological communities are reported as under threat or at risk of extinction, these are focused around urban areas, which have disrupted and destroyed patches of the native landscape (Fig. 1; DSEWPaC, 2010). This is only the tip of the

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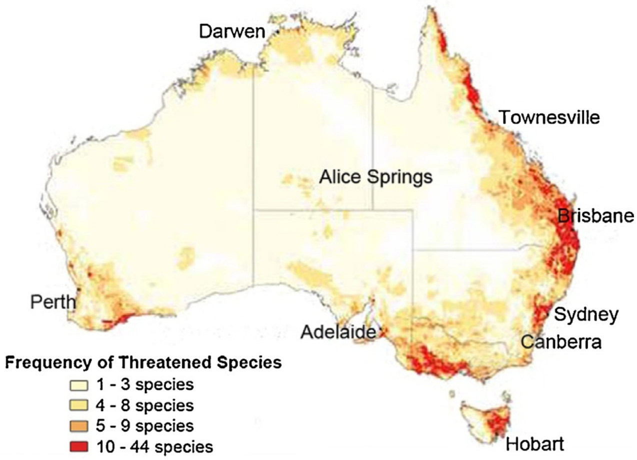

Fig. 1. Distribution of species listed as threatened under the Environment Protection and Biodiversity Conservation in Australia.

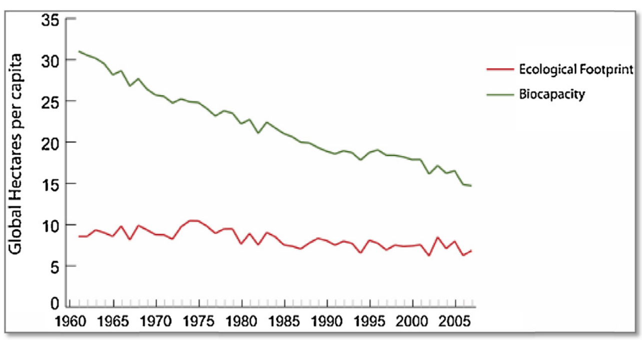

Fig. 2. Per capita resource demand (Ecological Footprint) and resource supply (Biocapacity) in Australia since 1961.

iceberg however, for every known species that is placed on the 'at risk' register there are many more that are affected by destruction of habitats and other threats.

Further, cities produce as much as 78% of greenhouse gas (GHGs) emissions, as well as creating urban 'heat island' effects which contribute significantly to global climate change, followed by increased disparity amongst ecosystem services, exacerbated urban pollution, reduced human health, altered water quality and food security (Arnfield, 2003; IPCC, 2007; Rosenzweig et al., 2010). Urban reliance on energy, resources and information to function, as well as uptake, transformation and storage of materials, and discharge of waste products, increases the interactions between socio-economic and biophysical forces (Cadenasso et al., 2006; Peters et al., 2008). For example, Australia's per capita ecological footprint in 2007 was (and continues to be) one of the largest in the world, sitting comfortably in the global top ten – 6.9 global hectares (Global Footprint Network, 2013; Fig. 2). Unless the global ecological footprint is stabilized there will be a tipping point, in the not too distant future, when the demand will outstrip the resource supply or bio-capacity (Meikle and Elkadi, 2012). Many cities are rapidly transforming into alternative paradigms of patterns and processes, working to address issues of sustainability and adapting to become new urban systems (Carpenter and Folke, 2006). For instance, since the 1970s, the per capita food, water and material consumption in Hong Kong have surged, and the pollution by fossil fuel emissions, atmospheric CO_2 outputs, municipal solid wastes and sewage discharges have become substantially higher (Warren-Rhodes and Koenig, 2001).

Urban design and planning have become considerable challenges as the values of spatial differentiation in urban landscapes are largely disregarded. There is limited consideration of the rapidly changing patterns and processes of urban ecosystem functions as a result of variations in growing human perception, choice, and action driven by political, economic and cultural decisions (Pickett and Cadenasso, 2008). There is a comprehensive knowledge gap on how urban ecosystems function within the complex mosaic of urban design and infrastructure such as building, landscape architecture and civil engineering, and the 'complementary' role they play in urban landscapes, fundamental components of urban planning. 'Complementary' stands for how mutually urban ecology and infrastructure developments can full-fill each other's deficiency. For example, the flora and fauna, along with urban building and surfaces, road and railway networks, are principle elements of urban structures that yield significant benefits both to local urban residents and the wider community, as well as creating and maintaining the systems 'down-stream' by providing significant refuge and networking through inter-habitat-connectivity (Halpern et al., 2008). Urban infrastructures, on the other hand, would act as habitat analogues for ecology (Lundholm and Richardson, 2010). Urban design and planning would also collectively benefit from an understanding of urban ecosystem structures and functions (Niemelä, 1999a).

Elements of "green infrastructure" comprising both natural and artificial habitats contribute to urban ecosystem health. For instance, urban and peri-urban habitats increase vegetation cover, and stream communities contribute to biological diversity and conservation, maintaining the integrity of systems and providing a physical basis for ecological networks (Hofmann et al., 2012). Human-designed ecological engineering (e.g. an artificial fish ladder in the river) helps overcome management issues of artificial habitats, makes urban ecosystems suitable for endemic fish species and assists in establishing a greater dispersal mechanism (Lundholm and Richardson, 2010). Indicator-based information entropies would reflect functioning, metabolism and sustainability of urban ecosystems (Zhang et al., 2006). The roles of urban designers and planners are therefore vital for achieving sustainable development of the city by understanding and maintaining 'green infrastructure' and urban ecosystem functioning to meet the growing demands of urban people for quality life space and public appreciation of infrastructures and natural environments. Learning cross-scale interactions and feedback mechanisms between urban design and human actions on ecosystem functions along temporal and spatial scales are significant at a time of increased demands in effective urban planning (Pickett and Cadenasso, 2008).

Development of a conceptual framework or theoretical model has the potential to resolve issues of management and sustainable use of urban landscapes to establish goals and evaluate outcomes, and provide useful inputs to urban growth management strategies (Anderson, 2006). Linking ecological and social systems is fundamental for sustainability of urban populations (Zipperer et al., 2011). For example, the Long Term Ecological Research (LTER) in the US suggests that for urban ecological systems a broader range of structural and functional relationships are often significant (Alberti, 2008; Pickett et al., 2009). Understanding the relationships between social status and awareness of environmental problems, and between human tribes or race and environmental hazards can produce better outcomes in urban ecosystems values (Grimm et al., 2000; Alberti, 2008; Pickett et al., 2008). Various conceptual frameworks and empirical models have been developed for land use change patterns in the context of species diversity, riparian function, and carbon and nitrogen dynamics in urban watersheds (Pickett et al., 2008, 2011; Niemelä et al., 2009). However, the majority of these models are bio-centric in nature, focusing mainly on ecological components with limited accounts given of decision making processes or effects of social drivers on ecosystems (Zipperer et al., 2011). A few alternative models, based on the theory