Novel Urban Ecosystems: new nature(s) for the Century of the City

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Introduction

The 21st century has been labeled the "Century of the City" because of the present and growing dominance of the world's urban population. The world has entered a new geological era, the Anthropocene, so labeled by Paul Crutzen and Eugene Stoermer in 2000 - in which the impacts and artifacts of humans are recognized as a geologic force. Clearly in this new human-dominated urban era, for the world to be sustainable and resilient, cities will need to play a leading role. Urban biodiversity, defined broadly and holistically here, will become key providers of the ecosystem services that cities depend on.

The changes that humans have made to the earth are visible from space, measurable in the planet's atmosphere, and can be sensed by all via the world's changing climate, rising sea levels, biodiversity loss, and changes to water and air quality, human health and the overall quality of life. We are now beginning to understand the consequences and complexities of our present, and future, urban existence (McPherson et al 2016, Forman 2014).

The world is undeniably in new and uncharted territory, the era of the Anthropocene – in which the impacts and artifacts of humans have become global in scale. In this context, the conventional wisdom that views "nature" and "cities" as opposites is no longer accurate and certainly not productive to meet current and future challenges. Marris et al. (2011) argue that the Anthropocene does not represent a human failure, but rather a call-to-action, … – and to develop a more opportunistic and "forward-looking nature".

The world's urban future needs new conceptions, paradigms and models for urban nature – including its appearance, its spatial dimensions, its functions and complexity, and ultimately it as a physical manifestation of human values and aspirations. The new global urban demography will cause humanity to rethink its most fundamental concepts and conceptions of nature. There is no going back to the pre-Anthropocene world. "We can only go forward and have to find the best way of making progress" (Sijmonds 2014).

In the Century of the City "urban nature" of all types, will be called on, directly and indirectly to contribute to the, feeding, clothing, sheltering, buffering, inspiring, rejuvenating, recreating, and otherwise sustaining a

population of 7 billion urban humans. To meet this challenge, a new conception of urban nature is needed (Hobbs et al. 2006, 2013, Marris et al. 2011). This is not to say, simplistically, that conventional notions of nature aren't viable, but rather that they be a included in a new, broader, holistic and inclusive conception of nature that more accurately accounts for the reality of nature in the new urban world (Ward Thompson 2002).

A typology of novel urban ecosystems

Urban ecosystems and urban landscapes are novel – in the sense of being new and different from what was known before. By definition, therefore, novel urban ecosystems have "no-analog" and are increasingly the subject of research to understand their origins, ecological trajectories and opportunities for developing new management goals and approaches (Hobbs et al. 2013, Hobbs et al. 2006). While much of the novel ecosystems research has focused on non-urban ecosystems, such as forests and agricultural landscapes, increasingly the concept is being applied in cities (Ross et al. 2015, Ahern 2016, Ahern 2014, Marris et al. 2011).

Urban ecology extends the spatial and functional perspectives of ecosystem and landscape ecology to cities – with a fundamental interest in the application of ecological theory and knowledge to address human-dominated landscapes, including urban landscapes and regions (Ross et al 2015, Forman 2014, McDonnell and Hahs 2013). Novel urban ecosystem theory builds on each of these seminal/sequential theories with the ambitious and synergistic agenda of advancing scientific knowledge through its application and a structured evaluation of the resulting landscape functionality and performance (Ahern 2013).

The United Nations Millennium Ecosystem Assessment defined four categories of ecosystem services that collectively represent the entirety of what humans need and receive from nature: Supporting, Provisioning, Regulating and Cultural Services (Millennium Ecosystem Assessment, 2006). Since its introduction by the UN, the ecosystem services concept has become an important tool in landscape and urban planning and design (Windhager et al 2010).

Here, I offer a "working" definition of novel urban ecosystems as: Ecosystems that persist or arise in cities, resulting from – and structured by - intentional or indirect human management actions (including inaction/abandonment); with unique species composition and structure influenced by biotic introductions and invasions; and that provide a suite of ecosystem services/disservices resulting from interactions of the biota with the altered abiotic urban environment (Ahern 2016).

This definition can be expanded to outline a typology of novel urban ecosystems including: Remnant/Restored, Abandoned/Ruderal, Horticultural/Formal, and Green Infrastructure-related. This typology is based on the level and type of urban biodiversity and species composition, and the extent of human intervention and management (see Figure 1). In Table 1, these four types are elaborated in terms of definition, examples, principal ecosystem services provided and design and design and management considerations.

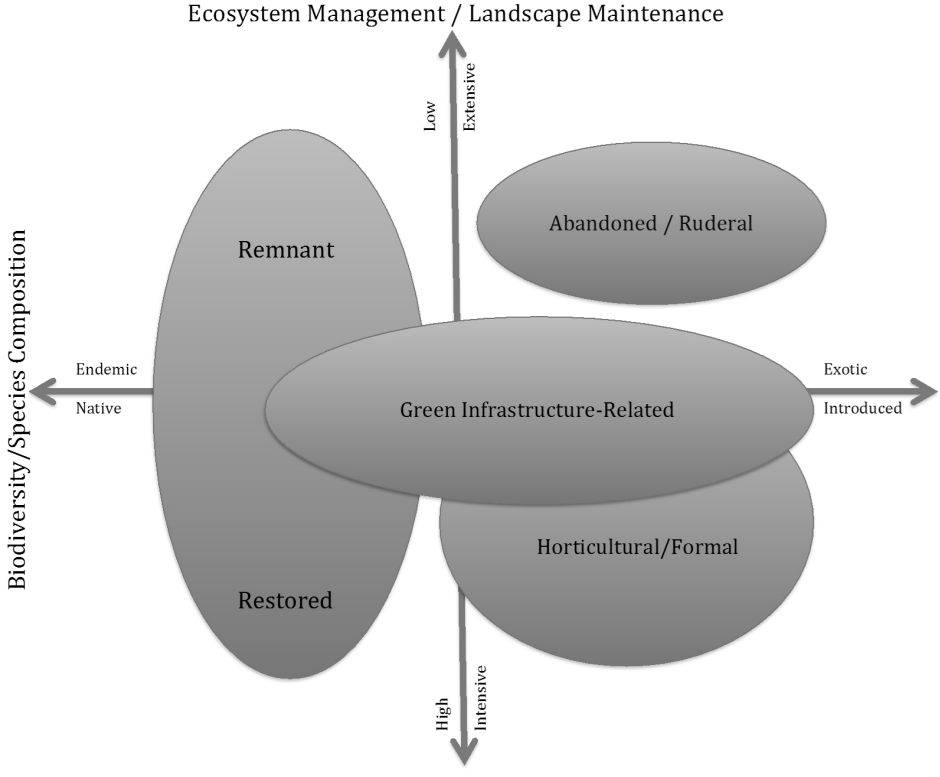

Figure 1. A typology for classifying novel urban ecosystems based on biodiversity /species composition and the type and intensity of human intervention/management. The boundaries of the four types of novel landscapes/ecosystems overlap and are illustrated as definitive, while in any particular context they are likely to be expressed as transitional gradients.

The novel urban ecosystems (NUE) typology is offered as one way to understand, through classification, how NUE's differ in terms of biotic diversity, the level of management, and initial considerations for urban landscape design and management. When NUE's are understood in these

terms, including the ecosystem services/disservices they provide, they can be more deliberately integrated into urban planning and design in support of sustainability and resilience goals (Table 2) (Speak et al 2015). Following are examples to illustrate the novel urban ecosystem typology in selected urban contexts.

Table 1. Typology of Novel Urban Ecosystems/Landscapes (definition, examples, principal ecosystem/landscape services, and design and management considerations.

	Remnant/Restored Native	Abandoned Ruderal	Horticultural Formal	Green Infrastructure-related
Definition	discrete patches remaining from pre or early stages of urbanization, or restored with moderate changes in species composition and vegetative structure.	spontaneous, non- or minimally managed, highly variable in vegetative structure and species composition, highly dynamic	intentionally made and managed for human use(s), particularly for aesthetic, social and recreation values.	The biotic component of some green infrastructure in combination with ecologically-engineered substrates and surfaces.
Examples	urban forest patches, marshes, riparian corridors, restored woodlands, wetlands	Brownfields, abandoned/ derelict lands, transportation verges, drosscapes.	parks, public and private gardens, allotment gardens cemeteries,	created wetlands, bioswales, greenroofs, bluebelts, many green infrastructure practices
Principal Ecosystem Services	specialist habitat, nutrient cycling, climatic buffer, stepping stones, stormwater infiltration, reference ecosystems, research and education	generalist/ exotic species habitat, some nutrient cycling, climatic buffer, stormwater infiltration,	climatic buffer, recreation, social venue, urban agriculture, moderate hydrological functions	Variable -predominantly based on hydrology, stormwater management, water quality, nutrient sequestration and climate mitigation
Design and Management Considerations	adaptation to climate change? potential invasion by exotic species,	highly dynamic – but manageable - vegetation composition and structure, potential source for invasive species, manage public perception	energy and labor intensive, generally high cultural acceptance, difficult to justify in a sustainability-conscious context	Safe-to-fail risk/opportunity to test novel concepts and combinations, monitoring and cost accounting particularly important

As the NES typology and examples illustrate, there is great variety in in origin, appearance, and ecosystem services provided. Relict NUE's provide a memory of the pre-urban ecosystem, and may serve as reference ecosystems to monitor response to climate and other changes and to serve as models for ecological restoration. Horticultural/Formal NUE's are familiar and tend to represent the popular understanding of "nature in the city". Green Infrastructure-related NUE's represent new, hybrid strategies to combine urban infrastructure with ecosystem services. Abandoned/Ruderal NUE's show the ecological response of urban biota to urban stresses, contaminants and abandonment related to economic or technological change (Del Tredici 2010).

Any of the NUE types may contribute to urban greenways – by closing connectivity gaps, providing new nodes, and by supporting cultural, educational and recreational uses and services.

Table 2. Selected Ecosystem Services and Ecosystem Disservices associated with Novel Urban Ecosystem Typology

	Remnant Native	Horticultural/ Formal	Green Infrastructure-Related	Abandoned Ruderal
Ecosystem Services				
wildlife habitat	***	*	*	**/***
stormwater interception/infiltration	***	**	*/***	***
water quality improvement	***	*/**	**/***	***
air quality improvement	***	**	**/***	***
climate mitigation	***	**	**	***
phytoremediation	*	-	**	***
carbon sequestration	***	**	*/**	**/***
aesthetic value	**	***	*/**	*
recreation, social interaction	**	***	*	*
sense of solitude, stress reduction	***	**	-	*/**
Ecosystem Disservices				
displace endemic vegetation	-	**	*	**/***
invasive species	-	-	*	***
pest habitat	-	-	*	**/***
water use for irrigation	-	***	-	-
energy use for management	-	***	*	-
nutrient runoff	-	**	-	-
respiratory allergies	*	-	-	**/***
maintenance costs	-	***	**	-
perceived unsafe	*	-	-	***
considered unattractive	-	-	*	***

Figure 1. The Prinzessinnengarten in Berlin Germany an Abandoned/Ruderal novel urban ecosystem used for urban agriculture and social gathering spaces.

Figure 2. "Nowadays" in New York City where Future Green Studio transformed an abandoned lot with dense growth of invasive vegetation into a popular beer garden through selective removal and strategic retention of the exotic/invasive vegetation - illustrating the Abandoned/Ruderal Novel Urban Ecosystem type.

Figure 3. A green parking lot in Portland, Oregon demonstrates the ecosystem service potential of green infrastructure, including stormwater interception/infiltration, wildlife habitat, and climate mitigation.

A Novel Ecosystem Strategy

Novel urban ecosystems are as much a new way of thinking about the urban environment as they are about understanding the current reality of urban nature. The basic rationale for this NUE strategy is that the challenges that 21st century cities face demand new solutions (McPherson et al 2016). The necessary solutions will need nature's help – and nature in the city is different and unique to each city based on its ecology, climate, history and state of development.

In addition to making our cities smarter and more efficient in multiple ways, we need to employ biodiversity to assist this unprecedented challenge (Hobbs et al 2013). Many novel urban ecosystems have important but latent (hidden) potential to provide ecosystems services. For example, scientists have learned that bacteria found in toxic/anaerobic environments can have the capacity to metabolize the very contaminants they live in. And these bacteria can then be employed to remediate other contaminated urban environments. A common urban plant species, Mugwort, Artemesia vulgaris, commonly considered to be an invasive pest, has been discovered to have phytoremediation capacities that can be employed to remediate brownfields (Kennon and Kirkwood, 2015). Mugwort is truly a jewel hidden in plain sight – waiting for its virtues to be discovered. Here is an interesting example of urban ecology where biodiversity has "learned" to process waste materials that are not found in

nature, but that exist in most cities. The challenge for NUE's is to better understand such urban biodiversity and the ecosystem services that it can deliver.

Novel urban ecosystems need to be understood at multiple scales – from the microscopic to the metro-region. At broader scales connectivity is important because many ecosystem services depend on corridors to form networks that operate at broader scales. Here urban greenways can be supported with NUEs. When connectivity is diminished, the functions that operate at broad scales are compromised. Landscape ecology has researched the effects of landscape fragmentation on species movement, colonization and survival over time, and has established the essential role of habitat connectivity.

This novel urban ecosystem strategy includes several key ideas. Urban biodiversity is not an oxymoron, but rather an essential resource and tool to deliver ecosystem services. Novel urban ecosystems need to be understood, planned, designed and managed at multiple scales to support the essential processes that function at those same scales. Novel urban ecosystems can be added to, or help to initiate urban greenways. For all of these ideas to be accepted, practiced and supported over time, a transdisciplinary mode of working is needed in which design professionals, scientists, decision makers and stakeholders share information and ideas continuously.

Conclusions

The century of the city poses unprecedented challenges for urban sustainability and urban resilience. Novel urban ecosystems of many types will survive, or result from future urbanization – intentionally and unintentionally. Paradoxically, NUE's may include ecological knowledge that evolves from and in polluted environments – knowledge that may contain the capacity to remediate the same toxins that often accompany urbanization.

The idea and promise of novel urban nature captures the important conclusion that has been drawn from the Century of the City – that the global challenge for sustainability and resilience will be won or lost in cities.

"The challenge of the Anthropocene is to use human ingenuity to set things up so that the planet can accomplish its 21st-century task." (Sijmonds 2014).

Landscape architects have an unprecedented opportunity to contribute to this global challenge. In the Anthropocene, nature is being redefined – to acknowledge the new and permanent urban reality, and to understand how novel urban ecosystems can deliver the ecosystem services that cities need,

and manage the ecosystem disservices for cities to be sustainable and resilient. Designers can partner with scientists and decision makers to practice adaptive design, through "safe-to-fail design" experiments – and to make a professional habit of monitoring and assessment to learn, specifically how this novel nature performs.

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