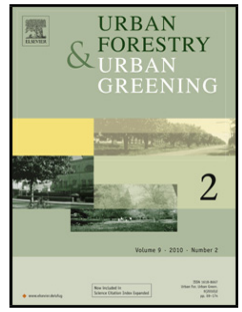
Accepted Manuscript



Title: The distinct ecological and social roles that wild spaces play in urban ecosystems

Authors: Caragh G. Threlfall, Dave Kendal

PII: S1618-8667(16)30472-1
DOI: http://dx.doi.org/doi:10.1016/j.ufug.2017.05.012
Reference: UFUG 25920

To appear in:

Received date: 3-11-2016
Revised date: 6-5-2017
Accepted date: 22-5-2017

Please cite this article as: Threlfall, Caragh G., Kendal, Dave, The distinct ecological and social roles that wild spaces play in urban ecosystems.Urban Forestry and Urban Greening http://dx.doi.org/10.1016/j.ufug.2017.05.012

The distinct ecological and social roles that wild spaces play in urban ecosystems

The distinct ecological and social roles that wild spaces play in urban ecosystems

Threlfall, Caragh G.[1], and Kendal, Dave[1,2]*
(both authors contributed equally)

[1] School of Ecosystem and Forest Sciences, The University of Melbourne

[2] Thrive Research Hub, Melbourne School of Design, Faculty of Architecture, Building and Planning, The University of Melbourne

* corresponding author

Email: dkendal@unimelb.edu.au Mobile: 0422993014
500 Yarra Boulevard, Richmond 3121, Victoria, Australia

The distinct ecological and social roles that wild spaces play in urban ecosystems
Highlights:

- Wild urban spaces are spatially and temporally dynamic
- And make a unique contribution to urban biodiversity and people's nature experience
- Wild urban spaces need explicit landscape management and planning
- They are likely to be increasingly important in future urban landscapes

Abstract

There is global interest in increasing the complexity of urban ecosystems to benefit both people and nature in cities. However, to successfully plan for and manage more complex landscapes greater attention is needed on understanding the complementary role of different types of green spaces in cities. Wild spaces occur in many forms across the landscape. In this paper, we discuss the different social and ecological roles that wild urban spaces play in our cities, and how they vary across space and time. We then assess the role and benefits of wild urban spaces in relation to other types of green space. Wild spaces are spatially and temporally diverse, and can act as refuges when other green spaces are not available. Many important differences exist in the composition, structure and management of wild spaces in comparison with other kinds of green space that drive their unique contribution to urban ecosystems. This discussion paper highlights these differences, and brings together knowledge of the role of wild spaces in urban landscapes from a multidisciplinary perspective.

Keywords: urban landscapes; green spaces; biodiversity; remnant ecosystems; wastelands; ecosystem services; wilderness

Introduction

Urban ecosystems contain a myriad of natural, constructed and hybrid spaces, where the combination of each is unique in every city and town. 'Wild' parts of urban ecosystems (wild spaces) can occur throughout the landscape, and have been studied from a variety of social and ecological perspectives. There is global interest in increasing the complexity of urban ecosystems to benefit both people and nature in cities (Pickett et al., 2016). However, to successfully plan for and manage more complex landscapes that have a variety of functional roles, greater attention is needed on understanding the complementary role of different types of green spaces in cities, including wild spaces, from a multidisciplinary perspective.

The term 'wild' is used in different ways across disciplines. It is often synonymous with 'wilderness', which is a very human term often referring to areas untouched by people (Cronon, 1995), or beyond human control (Kendal *et al.*, 2017). However, areas perceived to be wilderness are often the result of long-term human management (Cronon, 1995), and its reliance on the conception of humans as separate from nature is increasingly criticised (Braun, 2005). Wildness has also been characterised as the ability for an organism to respond to its base instincts (Cookson, 2011), or the capacity of an ecosystem to self-regulate (Kowarik, this issue). Here we define wild spaces quite broadly to encompass any space or component of an urban ecosystem (e.g. a patch within a park) where there is an absence of ongoing human intervention, where organisms are able to respond to their base instincts (e.g. through sexual reproduction) or self-assemble (Table 1). This includes areas of remnant native vegetation, abandoned lots and wastelands, railway verges and other informal greenspaces, large old trees and habitat patches in gardens.

Green spaces in cities are often studied in isolation. Many studies focus only on areas defined by land use, such as public parks, residential gardens or street tree networks (Kendal et al., 2012b). Following this tradition, many studies explore wild urban ecosystems separately as distinct land-use based entities in the landscape: as informal green spaces (e.g. Rupprecht & Byrne, 2014), spontaneously vegetated abandoned land ('wastelands') (Bonthoux et al., 2014), discreet patches of remnant vegetation (Zeeman et al., 2017), or designed meadows (Dunnett and Hitchmough, 2008). Of course, sometimes wild spaces do map to a distinct land use, for example in conservation reserves. Yet wild spaces can also occur within different land uses and across tenures: they exist as formally managed and unmanaged areas within neighbourhood parks, linear reserves and gardens, on public and private land, and as both large and small patches. Wild spaces are not confined to a particular land cover; they can exist as grasslands (Fischer et al., 2013), aquatic ecosystems (Walsh and Webb, 2016), and woodlands (Ramalho et al., 2014). They are present in 'interstitial' spaces (Jorgensen & Tylecote, 2007; Gandy, 2013), between or on the margins of more structured land uses: on derelict land and along river corridors. Most urban landscapes can contain wild spaces, such as unmanaged vegetation within golf courses (e.g. unmanaged areas of golf courses Threlfall et al., 2015), or wild animals that are not confined to 'wild' areas, such as highly mobile flying foxes (van der Ree et al., 2006).

Wild spaces are present in cities in many forms and in many places. They do not occur in isolation, and the role they play is shaped by the range of other green spaces present in the urban ecosystems they are part of. In this paper we draw upon the ecological and social sciences to answer the question "Where do wild spaces fit in the 'portfolio of places' needed for people and other organisms living in our cities?"

(sensu Swanwick, 2009). Importantly, this paper discusses wild spaces from both ecological and social perspectives. The characteristics of wild spaces that can differ from other kinds of green space are described and their spatial and temporal dimensions explored. These are linked to the kinds of social and ecological benefits provided by wild spaces, to illustrate their varied roles in urban landscapes.

Distinguishing different kinds of wild spaces from traditional green spaces

Several typologies of wild urban areas have been proposed typically based on landscape history and degree of transformation (Kowarik, 2011). Kowarik (see paper in this issue) distinguishes urban wilderness areas along a gradient from 'ancient' to 'novel' based on the composition of the system in comparison with historically known, naturally formed systems (which we will refer to as 'remnant'). These urban wilderness areas are distinguished from other kinds of green space along a gradient of self-regulation (naturalness of ecosystem processes). A particular interpretation of this second dimension distinguishes different kinds of ecosystems based on the degree of human involvement in community assembly processes (Table 1), where involvement is closely related to landscape management practices. This framework can be used to distinguish between different kinds of wild spaces and traditional green spaces. Spaces can be placed along a gradient of intervention from low (spontaneously forming systems), to high (systems where the community composition is fully managed by humans). There is an intermediate step on this gradient where composition is designed and constructed by the introduction of species or propagules, after which natural processes are largely allowed to determine community composition. Ecological restorations which mimic a historic template are distinguished from novel communities such as designed meadows, where a mix of forbs and graminoids is seeded and then managed using ecological disturbance (e.g. fire), or abandoned lots, which are seeded with lawn and then left unmanaged. In these cases, immigration, competition and reproduction are largely allowed to determine subsequent community composition and structure. This typology also allows different kinds of cultivated spaces to be distinguished based on reference to historic community templates e.g. native gardens where community assembly is designed and managed by humans (i.e. little or no natural assembly), but composition can be derived from historic templates.

[TABLE 1 HERE]

This typology is not mutually exclusive. For example spontaneous wasteland vegetation can be supplemented with exotic flowering species to improve public perception (Köppler et al., 2014), partially shifting these systems from spontaneous to designed. Shifts away from historic templates and towards spontaneous community assembly seem inevitable in many systems, particularly urban ones where there have been large environmental changes in comparison with historic environments (Grimm et al., 2008); further, there is growing recognition within ecology that restoration will now inevitably involve novel species and communities (Corlett, 2016).

Differences in scale and connectivity of wild urban spaces

Differences in scale, distribution, connectivity and permanence of urban wild spaces are some of the attributes that make these spaces unique (Table 2). For example, the scale of different kinds of wild spaces varies enormously from city to city, influenced by factors such as city size, age, density, and the rate of urbanisation (Rupprecht and Byrne, 2014). Wasteland and abandoned lots can be widespread in cities with declining populations; in Detroit, USA, vacant or abandoned land occupies a greater area than all other types of green space (Nassauer and Raskin, 2014). Remnant vegetation can be extensive in younger cities, where patches of high quality remnant vegetation remain (Hahs et al., 2009). Informal green space occupies approximately 5% of the urban area of Brisbane, Australia and Sapporo, Japan (Rupprecht and Byrne, 2014).

[TABLE 2 HERE]

Differences in the shapes and sizes of wild spaces influences their function in the landscape. Some are very large, including remnant terrestrial and aquatic ecosystems that occupy hundreds or thousands of hectares, while others can be very small such as wastelands that occupy a few hectares, or small islands of vegetation found on roundabouts that are a fraction of a hectare in size. Some are narrow and connected. Linear wild spaces such as riparian corridors, road verges and disused railway lines can play an important role in connecting habitat patches across urban areas, for example trees along median strips facilitated gene flow and connectivity between populations of white-footed mouse in New York

City (Munshi-South, 2012). Larger patches such as conservation reserves play a different role and can provide refuge for sensitive species and act as a source of propagules. Size and shape also influence the social functions that wild spaces have in cities. For example, riparian corridors and other wild linear spaces often also contain recreational infrastructure such as shared paths, and large wild areas can provide opportunities for functions such as recreational hiking and the study of nature that are otherwise often unavailable in cities (Konijnendijk, 2005).

Wild spaces are spatially dynamic at landscape scales (Table 2). While the location and structure of remnant areas may be relatively stable, the location of spontaneous ecosystems is constantly changing at the scale of a city, with continual abandonment, demolition, and construction altering their size and density (Bonthoux et al., 2014). Fluctuations in human population density influence the density and arrangement of wild ecosystems on road verges and vacant lots (Rupprecht and Byrne, 2014). They are also spatially heterogeneous; in some areas there may be a high density of small wild patches (e.g. roundabouts, road verges and utility corridors), while in others there may be a few larger patches (e.g. patches of remnant vegetation and large brownfield sites). In cities with declining populations, vacant lots are found in high densities in city centres, whereas in expanding cities they are more likely to occur on the periphery (Odom Green et al., 2016). Wild spaces are also spatially dynamic at local scales, as they can be in different stages of succession, supporting vegetation of different ages and composition (Bonthoux et al., 2014).The spatial complexity of wild ecosystems likely facilitates habitat complementarity at a landscape scale, where they provide habitat supporting high diversity in cities where other green spaces do not. The spatially dynamic nature of wild urban spaces can have important social consequences. Formal urban green spaces are provided unequally (Wolch *et al.*, 2014), and wild spaces can constitute a large part of the green space available in some disadvantaged areas (McPhearson *et al.*, 2013).

Similarly, wild ecosystems are temporally dynamic, which alters their ecological and social functions over time (Table 2). The age of wild ecosystems ranges widely, from long established remnant vegetation, to short–term wastelands and vacant lots. These newer and more temporary ecosystems have the potential to contribute significantly to connectivity across cities if linked to extant green spaces such as reserves (Odom Green et al., 2016). They may act as refugia, providing resources at critical times that are otherwise absent from other land uses, or from heavily managed green spaces. For example, there may be greater constancy in floral resources in vacant lots due to little human intervention, and this resource may allow for greater invertebrate diversity in times when other habitats are resource poor (Gardiner et al., 2014). Similarly, remnant ecosystems, informal green spaces and abandoned land can become increasingly important sources of accessible green space for people in areas undergoing urban renewal and infill development, which can result in the loss of traditional green spaces (Rupprecht and Byrne, 2014). An unintended consequence of the provision of formal greenspaces is gentrification (Wolch *et al.*, 2014), and providing green space through wild areas may be one way of minimising this.

Diversity, structure and composition of wild urban spaces

The plants in wild spaces can have very high levels of genetic diversity, as a result of sexual reproduction, while amenity landscapes are increasingly turning to the use of genetically uniform cultivars to improve the predictability of design and functional outcomes of landscapes (Lohr, 2013). In contrast, numerous studies show that in aggregation, amenity landscapes (particularly residential gardens) can have higher levels of taxonomic diversity than natural landscapes (Kendal et al., 2012b; Threlfall et al., 2016a), although some amenity landscapes have very low levels of both taxonomic and genetic diversity, such as monocultures of trees in mown turf. Both taxonomic and genetic diversity can lead to increased resilience of the system through increased redundancy (the same function being provided by multiple taxa) and response diversity (different taxa responding differently to the same environmental stress) in the system (Elmqvist et al., 2003). Sexual reproduction and environmental pressures can lead to natural selection in wild plants in remnants that are not likely to occur other landscapes e.g. amenity landscapes (Cheptou et al., 2008). There has been relatively little exploration of the human dimensions of genetic diversity, such as aesthetic preference (Botzat *et al.*, 2016), although one study has found that genetically diverse plant material can be preferred (Kendal et al., 2008).

Structural complexity is also another important characteristic that can differ between wild spaces and other green spaces. Structural complexity can be lower in more managed landscapes as complexity is restricted to improve surveillance and ease of management of landscapes (Hitchmough, 1994). In contrast, fewer such restrictions are typically placed on remnants or wastelands (Rupprecht *et al.*, 2015). A related characteristic is the influence of stochastic processes including sexual reproduction, mutation, competition and disturbance that can lead to unexpected effects on composition and structure, and consequently make places that are different to others, contributing to a unique sense of place (Jorgensen & Stedman, 2006). The effect of these processes can be stronger in wild ecosystems than in landscapes where composition is predetermined, reproduction largely eliminated and disturbance controlled to facilitate the persistence of individuals. This complexity in composition and structure of vegetation in wild ecosystems supports a greater diversity of species (Bonthoux *et al.*, 2014; Rupprecht *et al.*, 2015), including rare native species but also exotic species. There is mixed evidence on public support for structurally complex landscapes. Information processing theory suggests that people prefer moderately complex landscapes and that 'coherence' is also an important predictor of landscape preference, and it has been suggested that wild landscapes may not be preferred as they are too complex and lack coherence (Kaplan and Kaplan, 1989). However, recent empirical studies show that some people can prefer more complex, unstructured landscapes (e.g. Harris et al., 2017) and that this can be based on individual traits such as personality (van den Berg and van Winsum-Westra, 2010).

The composition of plants and animals in wild spaces often differs from other kinds of landscapes. This distinct composition also differentiates these landscapes from those occurring in other cities, also contributing to a stronger sense of place. There is a growing recognition that threatened species are well-represented in our cities (Ives et al., 2016) and wild spaces can harbor threatened or rare species (e.g. Bonthoux et al., 2014). This occurs either as remnant plants in native ecosystems, or by providing food and habitat for threatened animals, such as populations of the endangered white-ear, which successfully breeds in urban wastelands in Berlin, Germany (Meffert et al., 2012). Nativeness can also be an important predictor of preference, with some people in the community strongly preferring native plants, perhaps due to an understanding of the broader environmental benefits they may provide (Kendal et al., 2012a).

Benefits of wild areas in comparison with other kinds of urban green space

Urban green spaces provide well documented benefits, including ecosystem services such as cooling and carbon sequestration, human health and wellbeing benefits such as increases in physical activity and psychological restoration, and they provide habitat for other species (Bolund and Hunhammar, 1999; Bowler et al., 2010). Many of these benefits are also provided by wild spaces (Mathey et al., 2015, see also Kowarik this issue). However, it is the differences between the benefits provided by wild spaces and other kinds of green space that drive their unique contribution to urban systems. These benefits are largely determined by the biophysical characteristics of those spaces (Hunter and Luck, 2015), so understanding differences in these characteristics is a useful place to start exploring variation in benefits (Table 3)

[TABLE 3 HERE]

Habitat for other organisms

Wild spaces can provide habitat for fauna that would not otherwise be present in cities. The diversity of features contained within wild spaces encourages biodiverse communities to persist; local and landscape scale features of wild spaces are important for retaining biodiversity (Beninde et al., 2015; Bonthoux et al., 2014). At a local scale, the size, microclimate, soil and vegetation present within wild spaces influences the types of biodiversity they support (Beninde et al., 2015; Bonthoux et al., 2014; Rupprecht et al., 2015; Threlfall et al., 2016b, 2015). Vacant lots can contain a diversity of flowering forbs and grass species which support populations of generalist arthropod predators, including those that perform important biocontrol services (Gardiner et al., 2014) that are otherwise lost with frequent mowing, or in newly established green spaces. A lack of soil disturbance in wild spaces also benefits fauna, in comparison with spaces that are more frequently visited or disturbed (e.g. residential gardens, public parks). For example many predatory flies from the Dolichopodidae forage on larvae found within soils, which may occur less frequently in spaces that are mulched, heavily irrigated and compacted, such as community gardens (Gardiner et al., 2014).

Aesthetics and preference

Wild spaces have an increasingly important role in the aesthetics of urban places. The spontaneous wastelands of de-industrializing cities have inspired landscape and urban designers, and can be seen in high profile landscapes such as the Highline in New York (Gandy, 2013). While aesthetic responses to wild landscapes are often mixed (e.g. Mathey et al., 2016), there is some evidence that the general public's preferences are changing to become more favourable to wild spaces. Some studies show that people are increasingly preferring more wild elements of landscapes such as fallen wood (Lindhagen and Hörnsten 2000 reported in Hauru et al., 2014; Konijnendijk, 2005), and dense vegetation (Harris et al., 2017). While it is often assumed that people do not prefer 'messy' landscapes (Nassauer, 1995), recent research shows that different people have varied preferences for different kinds of landscapes (Botzat et al., 2016). Some people clearly do prefer wild spaces (Jorgensen et al., 2007; Southon et al., 2017; van den Berg and van Winsum-Westra, 2010) and wild spaces can be favoured by nearby residents (Jorgensen et al., 2005). These findings are consistent with people in post-industrial societies developing a more mutualistic rather than utilitarian/dominionistic relationship with nature (e.g. Manfredo et al., 2015).

The combination of stochastic processes, genetic, taxonomic and structural diversity that can occur in wild spaces means that they can have a stronger natural aesthetic (Botzat et al., 2016; Dyson, 2009). Wild spaces can look more unpredictable as the height, leaf colour, leaf size and flowering of plants can vary due to sexual variation and phenotypic plasticity. Plants in amenity landscapes have a more predictable expression of morphological traits due to restrictions on sexual reproduction and greater control over environmental parameters and disturbance. Traditional amenity landscapes include plants that have been deliberately selected for particular aesthetic characteristics (that may make landscapes less resilient and more vulnerable to environmental change or disturbance such as drought: Wilson *et al.*, 2016) that may be largely absent from wild spaces. Overall levels of 'greenness' may also differ, as wild spaces rarely feature the intense green of mown turf, and a number of common amenity trees and shrubs have strongly green foliage (Kendal et al., 2012a).

People's perception of urban green spaces is not all about preference. Bauer (2005) identifies a useful typology for understanding how people's attitudes to wild spaces can differ from other kinds of green spaces, based on landscape attributes such as Beauty, Diversity, Contrast (being different from everyday landscapes), Usefulness (e.g. hunting, skiing), Safety, Past as a reference point, and Freedom from regulation. Wild spaces provide urban dwellers with the direct experience of natural landscapes and ecosystem processes such as the phenology of leaf burst, flowering, autumn colour and sightings of migratory birds (Konijnendijk, 2005). These experiences have a potentially important role in providing opportunities for education and research (Konijnendijk, 2005), but perhaps more importantly in improving people's connectedness to nature, which is thought to generate support for conservation more generally (Miller and Hobbs, 2002).

Health and other human benefits

Natural environments are widely accepted as having positive impacts on the health and wellbeing of urban dwellers (Bowler et al., 2010). This has largely been explored within the context of traditional green spaces such as public parks (Giles-Corti et al., 2005). Calls have been made to develop better understanding of the qualities and characteristics of natural areas that are linked to health outcomes (Hunter and Luck, 2015; Jorgensen and Gobster, 2010). Some characteristics of some wild spaces suggest they can also make important contributions to health and wellbeing outcomes. A few studies have related increasing species diversity to psychological benefits (Fuller et al., 2007). Linear corridors along creeks and rivers provide opportunities for active commuting and active recreation such as jogging, and large wild urban woodlands provide opportunities for hiking and long duration nature experiences.

One fascinating line of enquiry currently being explored is the effect of microbial biodiversity on human health outcomes (Sandifer et al., 2015). It could be that the wild spaces in our intestines (Lozupone et al., 2012) and our skin (Hanski et al., 2012) provide great health benefits. Another important area of research is the role of wild spaces in childhood development (Kahn, 1997). There is widespread concern that childhood access to nature is declining along with opportunities for unstructured play (Louv, 2005). However, the wild spaces that occur in cities allow children to imagine a world that is not ordered by adults (Cloke and Jones, 2005), and will perhaps play an increasingly important role in the lived experience of children in our future cities.

Ecosystem services

While wild spaces can generate many important ecosystem services, it is difficult to generalize about the comparative provision of many services as service provision is strongly related to vegetation structure and cover (Bolund and Hunhammar, 1999), and the structure of wild spaces can vary considerably. In general, wild spaces containing trees are likely to provide similar levels of cooling, air pollution reduction and stormwater interception as other traditional green spaces with trees. Vacant lots in New York City were demonstrated to provide substantial services including stormwater mitigation, carbon sequestration and storage, space for recreation, and biodiversity habitat (McPhearson *et al.*, 2013). However, the provision of food is highly variable and likely to be determined by factors including the amount of arable land available, the tenure of such land and its viability for food production purposes (McClintock *et al.*, 2013). For example, in studies that asses the amount of vacant or under-utilised space available for food production in US cities, some estimate these may produce from 3% (McClintock *et al.*, 2013) and up to 48% (Grewal & Grewal, 2012) of a cities fresh produce requirements. The lack of intense management and the presence of low lying vegetation means that habitat provisioning services can be high in some types of wild spaces (Robinson and Lundholm, 2012), which allow them to support populations of animals that provide services such as biocontrol (Gardiner et al., 2014). The presence of understorey vegetation and leaf litter in remnant ecosystems also supports more abundant and diverse communities of animals that play a vital role in decomposition and nutrient cycling, including macro-detritivores, in comparison to green spaces that have more heavily managed or simple vegetation, such as parks (Ossola et al., 2016).

Ecosystem disservices

While there is mush research interest in the positive aspects of wild spaces, to some people they are scary, disgusting and uncomfortable (Bixler and Floyd, 1997). People experiencing wild forests vs tended forest tended to have lower levels of positive emotions and higher levels of negative emotions (Martens et al., 2011) and littering can also be perceived as a problem in some informally managed wild areas (Rupprecht et al., 2015). Wild spaces may be perceived to be less safe where vegetation can obscure surveillance (Jorgensen et al., 2002), they may provide fewer cultural heritage cues, and less recreational services e.g. opportunities for active sports (Konijnendijk, 2005). Wild spaces can also harbour wild animals that can damage other landscapes (e.g. wild boar in Berlin), be a vector for Lyme disease (Konijnendijk, 2005) or mosquito-borne viruses such as West Nile virus (Johnson et al., 2012).

How does the management of wild spaces differ from traditional urban green spaces?

An important distinguishing feature of wild spaces is the way they are managed. Traditional amenity landscapes use a set of well-defined management practices including mowing, pruning, dead wood removal and weed control to maintain a stable landscape appearance and reduce risk (Hitchmough, 1994). In contrast, wild spaces are often the result of reduced or absent management. Hence, there is a growing recognition that some wild spaces that require relatively low levels of management intervention, such as spontaneous vegetation in wastelands, vacant and derelict sites, or high quality remnant vegetation, can be a relatively cost effective method to increase the provision of ecosystem services in urban areas. Vacant lots for example are often initially planted with a turf grass mix and then left unmanaged. Gardiner et al (2014) demonstrate that at the site scale, both vacant lots and lots converted to community gardens contribute equally to urban biodiversity, suggesting that vacant lots are a very cost-effective way to support biodiversity in cities. Similarly, wastelands that contain a limited number of planted species can, with little human intervention, have the potential to contribute to cost-effective, multi-functional green space in cities, particularly in developing countries (Kitha and Lyth, 2011).

Many kinds of wild spaces are not commonly incorporated into urban planning, despite their role in providing ecological and social benefits. Non-traditional forms of wild spaces are sometimes part of corridor planning, for example featuring in green ways across cities in the form of ruderal and seminatural habitats (Angold et al., 2006). Areas containing wild vegetation such as wastelands and disused rail yards have also increasingly been considered in peri-urban green space systems in Europe, especially on the periphery of cities (Henne, 2005) and in the open space system of Germany (Kowarik & Langer, 2005). Urban planning tools have also been developed for brownfields in order to assist decision makers in prioritizing sites for re-development based on criteria such as population density, property value and past land use (as an indicator of potential contamination) (Chrysochoou et al., 2012). However these criteria do not acknowledge the ecological or social value of such sites (Bonthoux et al., 2014), nor do they include other forms of wild spaces. A spatially explicit social-ecological tool developed by McPhearson et al (2013) has been applied to vacant lots in New York City, demonstrating the value of considering the social and ecological attributes of vacant land from a planning perspective. Future planning could include the role of wild spaces as temporary spaces. Modelling studies demonstrate spaces such as wastelands can support high species diversity if left for 15 years prior to re-development (Kattwinkel et al., 2011). This however requires a dynamic approach to management of and planning for wild spaces, that includes both spatial and temporal aspects, allowing some sites to be developed whilst retaining or creating sites in other parts of the landscape (Kattwinkel et al., 2011).

The governance of urban green spaces is complicated, with large knowledge gaps, particularly in developing countries (Elmqvist et al., 2013). The governance of different kinds of wild spaces varies considerably. Remnant ecosystems can be governed by a myriad of local, state and federal laws that protect native ecosystems and threatened species, particularly in developed countries. In contrast, novel wild spaces on abandoned land can be the result of an absence of governance, where formal and informal regulation of private residential, commercial or government land owners has failed (Odom Green et al., 2016). Governance of vacant land is particularly complex where multiple outcomes such as biodiversity and ecosystem services are desired (Odom Green et al., 2016). At the scale of a city, wild spaces and traditional forms of green space are ‘mutually reinforcing’, by co-supporting biodiversity and ecosystem services, and hence benefit from improved planning and management to facilitate resilient and sustainable city ecosystems (Odom Green et al., 2016). Increasingly the public is involved in the governance of natural areas (Berkes, 2007). While there have been calls for the use of participatory management of non-traditional wild urban spaces to ensure alignment with public interests, there has been relatively little investigation of community involvement in governance of these spaces (Rupprecht et al., 2015).

The future of wild urban spaces

All landscapes are the outcome of slow historical processes. Wild urban spaces are no exception. They are shaped by social processes such as conservation legislation and land abandonment (Kowarik, 2011), and ecological processes such as competition, dispersal and ecological drift (Johnson and Handel, 2016). Some processes pose threats to the future of some forms of wild spaces. There is great concern about the degrading effects of introduced species on remnant areas, while these same introduced species are vital to the existence of spontaneous vegetation in wastelands. Vacant plots are increasingly being converted to community gardens (Gardiner et al., 2014). Urban densification policies lead to a loss of wastelands when they are converted to other land uses (Dallimer et al., 2011).

Despite these threats, it is perhaps likely that we will have more wild spaces in our future cities. The social and economic changes leading to land abandonment continue apace in many cities around the world (Kowarik, 2005). Increasing awareness of the risks of chemicals may lead to a reduction in herbicide use, in turn leading to more spontaneous vegetation in our cities. Wild animals are moving into our cities in response to increased availability of resources and habitat (e.g. van der Ree et al., 2006). There are also important changes in the way society is thinking about natural systems. Wild urban spaces may be increasingly acceptable in post-industrial societies that are developing a more mutualistic relationship with wild nature (Manfredo et al., 2015). There is an increased awareness of the importance of cities for the protection of biodiversity (Ives et al., 2016), and increasing acceptance of the role that unmanaged forests can play in the future (Schnitzler, 2014).

Global environmental change is arguably most evident in cities. Rapidly changing climate, hydrology, and biogeochemical processes is leading to unpredictable ecosystem responses. No matter how much we attempt to control the landscapes we live with, wild spaces, wild animals and wild places will continue to survive and thrive in our cities. The London that has returned to the jungle described by J

G Ballard in ‘The Drowned World’ may be less than fictional from both social and ecological perspectives (Gandy, 2006). We need to better understand the role of different kinds of wild spaces in rapidly changing social-ecological systems to successfully plan for and manage more complex landscapes.

Acknowledgements

Both authors are supported by the Clean Air and Urban Landscapes Hub, which is funded by the Australian Government's National Environmental Science Programme.

We would like to thanks two anonymous reviewers whose comments have led to a greatly improved manuscript.

References

Angold, P.G., Sadler, J.P., Hill, M.O., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R., Thompson, K., 2006. Biodiversity in urban habitat patches. Sci. Total Environ. 360, 196–204.

Bauer, N., 2005. Attitudes towards wilderness and public demands on wilderness areas, in: Wild Urban Woodlands: New Perspectives for Urban Forestry. pp. 47–66.

Beninde, J., Veith, M., Hochkirch, A., 2015. Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. 18, 581–592. doi:10.1111/ele.12427

Berkes, F., 2007. Community-based conservation in a globalized world. Proc. Natl. Acad. Sci. U. S. A. 104, 15188–93. doi:10.1073/pnas.0702098104

Bixler, R.D., Floyd, M.F., 1997. Nature is Scary, Disgusting, and Uncomfortable. Environ. Behav. 29, 443–467. doi:10.1177/001391659702900401

Bolund, P., Hunhammar, S., 1999. Ecosystem services in urban areas. Ecol. Econ. 29, 293–301. doi:10.1016/S0921-8009(99)00013-0

Bonthoux, S., Brun, M., Di Pietro, F., Greulich, S., Bouché-Pillon, S., 2014. How can wastelands promote biodiversity in cities? A review. Landsc. Urban Plan. 132, 79–88. doi:10.1016/j.landurbplan.2014.08.010

Botzat, A., Fischer, L.K. & Kowarik, I. (2016) Unexploited opportunities in understanding liveable and biodiverse cities. A review on urban biodiversity perception and valuation. Global Environmental Change, 39, 220-233.

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

Braun, B. (2005) Environmental issues: writing a more-than-human urban geography. Progress in human geography, 29, 635-650.

Cheptou, P.-O., Carrue, O., Rouifed, S., Cantarel, a, 2008. Rapid evolution of seed dispersal in an urban environment in the weed Crepis sancta. Proc. Natl. Acad. Sci. U. S. A. 105, 3796–3799. doi:10.1073/pnas.0708446105

Chrysochoou, M., Brown, K., Dahal, G., Granda-Carvajal, C., Segerson, K., Garrick, N., Bagtzoglou, A., 2012. A GIS and indexing scheme to screen brownfields for area-wide redevelopment planning. Landsc. Urban Plan. 105, 187–198. doi:10.1016/j.landurbplan.2011.12.010

Cloke, P., Jones, O., 2005. “Unclaimed territory”: childhood and disordered space(s). Soc. Cult. Geogr. 6, 311–333. doi:10.1080/14649360500111154

Cookson, L.J. (2011) A definition for wildness. Ecopsychology, 3, 187-193.

Corlett, R.T., 2016. Restoration, Reintroduction, and Rewilding in a Changing World. Trends Ecol. Evol. 31, 453–462. doi:10.1016/j.tree.2016.02.017

Cronon, W. (1995) The trouble with wilderness; or, getting back to the wrong nature. Uncommon ground: rethinking the human place in nature. (ed. by W. Cronon), pp. 69–90. W.W. Norton & Company, New York.

Dallimer, M., Tang, Z., Bibby, P.R., Brindley, P., Gaston, K.J., Davies, Z.G., 2011. Temporal changes in greenspace in a highly urbanized region. Biol. Lett. 763–766. doi:10.1098/rsbl.2011.0025

Dobbs, C., Escobedo, F., Zipperer, W., 2011. A framework for developing urban forest ecosystem services and goods indicators. Landsc. Urban Plan. 99, 196–206. doi:10.1016/j.landurbplan.2010.11.004

Dobbs, C., Kendal, D., Nitschke, C.R., 2014. Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and sociodemographics. Ecol. Indic. 43, 44–55. doi:10.1016/j.ecolind.2014.02.007

Dunnett, N., Hitchmough, J., 2008. The Dynamic Landscape: Design, Ecology and Management of Naturalistic Urban Planting. Taylor & Francis.

Dyson, C., 2009. Vulnerable scenery: the shifting dynamics of a natural aesthetic in the Australian postwar garden, in: (Un)Loved Modern. Australia ICOMOS, Sydney, pp. 1–9.

Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, J., Walker, B., Norberg, J., 2003. Response diversity, ecosystem change, and resilience. Front. Ecol. Environ. 1, 488–494. doi:10.2307/3868116

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P.J., McDonald, R.I., Parnell, S., Schewenius, M., Sendstad, M., Seto, K.C., Wilkinson, C., Alberti, M., Folke, C., Frantzeskaki, N., Haase, D., Katti, M., Nagendra, H., Niemelä, J., Pickett, S.T.A., Redman, C.L., Tidball, K., 2013. Stewardship of the Biosphere in the Urban Era, in: Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities.

Fischer, L.K., Lippe, M. Von Der, Rillig, M.C., Kowarik, I., 2013. Creating novel urban grasslands by reintroducing native species in wasteland vegetation. Biol. Conserv. 159, 119–126. doi:10.1016/j.biocon.2012.11.028

Fuller, R.A., Irvine, K., Devine-Wright, P., Warren, P., Gaston, K., 2007. Psychological benefits of greenspace increase with biodiversity. Biol. Lett. 3, 390–394. doi:10.1098/rsbl.2007.0149

Gandy, M., 2006. The Drowned World: J. G. Ballard and the Politics of Catastrophe. Sp. Cult. 9, 86–88. doi:10.1177/1206331205283732

Gandy, M., 2013. Marginalia: Aesthetics, Ecology, and Urban Wastelands. Ann. Assoc. Am. Geogr. 103, 1301–1316. doi:10.1080/00045608.2013.832105

Gardiner, M.M., Prajzner, S.P., Burkman, C.E., Albro, S., Grewal, P.S., 2014. Vacant land conversion to community gardens: Influences on generalist arthropod predators and biocontrol services in urban greenspaces. Urban Ecosyst. 17, 101–122. doi:10.1007/s11252-013-0303-6

Giles-Corti, B., Broomhall, M.H., Knuiman, M., Collins, C., Douglas, K., Ng, K., Lange, A., Donovan, R.J., 2005. Increasing walking: how important is distance to, attractiveness, and size of public open space? Am. J. Prev. Med. 28, 169–76. doi:10.1016/j.amepre.2004.10.018

Gill, N., Waitt, G., Head, L., 2009. Local engagements with urban bushland: Moving beyond bounded practice for urban biodiversity management. Landsc. Urban Plan.

Goodness, J., Andersson, E., Anderson, P.M.L., Elmqvist, T., 2016. Exploring the links between functional traits and cultural ecosystem services to enhance urban ecosystem management. Ecol. Indic. 70, 597–605. doi:10.1016/j.ecolind.2016.02.031

Grahn, P. & Stigsdotter, U.K. (2010) The relation between perceived sensory dimensions of urban green space and stress restoration. Landscape and Urban Planning, 94, 264-275.

Grewal, S.S. & Grewal, P.S. (2012) Can cities become self-reliant in food? Cities, 29, 1-11.

Grimm, N.B., Faeth, S., Golubiewski, N., Redman, C., Wu, J., Bai, X., Briggs, J., 2008. Global Change and the Ecology of Cities. Science (80-.). 319, 756–760. doi:10.1126/science.1150195

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., Gomez-Baggethun, E., Gren, A., Hamstead, Z., Hansen, R., Kabisch, N., Kremer, P., Langemeyer, J., Rall, E.L., McPhearson, T., Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster, D., Elmqvist, T., 2014. A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. Ambio 43, 413–33. doi:10.1007/s13280-014-0504-0

Hahs, A.K., McDonnell, M.J., McCarthy, M., Vesk, P., Corlett, R., Norton, B., Clemants, S.E., Duncan, R.P., Thompson, K., Schwartz, M.W., Williams, N., 2009. A global synthesis of plant extinction rates in urban areas. Ecol. Lett. 12, 1165–1173. doi:10.1111/j.1461-0248.2009.01372.x

Hanski, I., von Hertzen, L., Fyhrquist, N., Koskinen, K., Torppa, K., Laatikainen, T., Karisola, P., Auvinen, P., Paulin, L., Makela, M.J., Vartiainen, E., Kosunen, T.U., Alenius, H., Haahtela, T., 2012. Environmental biodiversity, human microbiota, and allergy are interrelated. Proc. Natl. Acad. Sci. 109, 8334–8339. doi:10.1073/pnas.1205624109

Harris, V., Kendal, D., Hahs, A. & Threlfall, C.G. (2017) Green space context and vegetation complexity shape people’s preferences for urban public parks and residential gardens. Landscape Res., 1-13.

Hauru, K., Koskinen, S., Kotze, D.J., Lehvävirta, S., 2014. The effects of decaying logs on the aesthetic experience and acceptability of urban forests – Implications for forest management. Landsc. Urban Plan. 123, 114–123. doi:10.1016/j.landurbplan.2013.12.014

Henne, S.K. (2005) “New Wilderness” as an Element of the Peri-Urban Landscape. Wild Urban Woodlands (ed. by I. Kowarik and S. Korner), pp. 247-262. Springer.

Hitchmough, J., 1994. Urban Landscape Management. Inkata Press.

Hitchmough, J., de la Fleur, M., 2006. Establishing North American prairie vegetation in urban parks in northern England: Effect of management and soil type on long-term community development. Landsc. Urban Plan. 78, 386–397.

Hunter, A.J., Luck, G.W., 2015. Defining and measuring the social-ecological quality of urban greenspace: A semi-systematic review. Urban Ecosyst. doi:10.1007/s11252-015-0456-6

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. Glob. Ecol. Biogeogr. 25, 117–126. doi:10.1111/geb.12404

Johnson, B.J., Munafo, K., Shappell, L., Tsipoura, N., Robson, M., Ehrenfeld, J., Sukhdeo, M.V.K., 2012. The roles of mosquito and bird communities on the prevalence of West Nile virus in urban wetland and residential habitats. Urban Ecosyst. 15, 513–531. doi:10.1007/s11252-012-0248-1

Johnson, L.R., Handel, S.N., 2016. Restoration treatments in urban park forests drive long-term changes in vegetation trajectories. Ecol. Appl. 26, 940–956. doi:10.1890/14-2063/suppinfo

Jorgensen, A. & Tylecote, M. (2007) Ambivalent landscapes—wilderness in the urban interstices. Landscape Research, 32, 443-462.

Jorgensen, A., Gobster, P.H., 2010. Shades of Green: Measuring the Ecology of Urban Green Space in the Context of Human Health and Well-Being. Nat. Cult. 5, 338–363. doi:10.3167/nc.2010.050307

Jorgensen, A., Hitchmough, J., Calvert, T., 2002. Woodland spaces and edges: their impact on perception of safety and preference. Landsc. Urban Plan. 60, 135–150.

Jorgensen, A., Hitchmough, J., Dunnett, N., 2005. Living in the Urban Wildwoods : A Case Study of Warrington New Town, in: Wild Urban Woodlands: New Perspectives for Urban Forestry. pp. 95–116.

Jorgensen, A., Hitchmough, J., Dunnett, N., 2007. Woodland as a setting for housing-appreciation and fear and the contribution to residential satisfaction and place identity in Warrington New Town, UK. Landsc. Urban Plan. 79, 273–287.

Jorgensen, B.S., Stedman, R.C., 2006. A comparative analysis of predictors of sense of place dimensions: attachment to, dependence on, and identification with lakeshore properties. J. Environ. Manage. 79, 316–27. doi:10.1016/j.jenvman.2005.08.003

Kahn, P., 1997. Developmental Psychology and the Biophilia Hypothesis: Children's Affiliation with Nature, ,. Dev. Rev. 17, 1–61. doi:10.1006/drev.1996.0430

Kaltenborn, B., Bjerke, T., 2002. Associations between environmental value orientations and landscape preferences. Landsc. Urban Plan. 59, 1–11.

Kaplan, R., Kaplan, S., 1989. The experience of nature: a psychological perspective. Cambridge University Press.

Kattwinkel, M., Biedermann, R., Kleyer, M., 2011. Temporary conservation for urban biodiversity. Biol. Conserv. 144, 2335–2343. doi:10.1016/j.biocon.2011.06.012

Kaufman, A.J., Lohr, V.I., 2004. Does plant color affect emotional and physiological responses to landscapes? Acta Hortic. 639, 229–233.

Kendal, D., Robin, L., Wilson, A., Muir, C., Pearce, L.M., Willoughby, S. & Lunt, I.D. (2017) Led up the garden path? Weeds, conservation rhetoric, and environmental management. Australasian Journal of Environmental Management, 1-14.

Kendal, D., Williams, K., Armstrong, L., 2008. Preference for and performance of some Australian native plants grown as hedges. Urban For. Urban Green. 7, 93–106. doi:10.1016/j.ufug.2008.02.002

Kendal, D., Williams, K.J.H., Williams, N.S.G., 2012a. Plant traits link people's plant preferences to the composition of their gardens. Landsc. Urban Plan. 105, 34–42. doi:10.1016/j.landurbplan.2011.11.023

Kendal, D., Williams, N.S.G., Williams, K.J.H., 2012b. Drivers of diversity and tree cover in gardens, parks and streetscapes in an Australian city. Urban For. Urban Green. 11, 257–265. doi:10.1016/j.ufug.2012.03.005

Kitha, J., Lyth, A., 2011. Urban wildscapes and green spaces in Mombasa and their potential contribution to climate change adaptation and mitigation. Environ. Urban. 23, 251–265. doi:10.1177/0956247810396054

Konijnendijk, C.C., 2005. New Perspectives for Urban Forests : Introducing Wild Woodlands, in Kowik, I. & Körner S. (eds) Wild Urban Woodlands: New Perspectives for Urban Forestry. pp. 33–45. Springer

Köppler, M.-R., Kowarik, I., Kühn, N., von der Lippe, M., 2014. Enhancing wasteland vegetation by adding ornamentals: Opportunities and constraints for establishing steppe and prairie species on urban demolition sites. Landsc. Urban Plan. 126, 1–9. doi:10.1016/j.landurbplan.2014.03.001

Kowarik, I. & Langer, A. (2005) Natur-Park Südgelände: Linking conservation and recreation in an abandoned railyard in Berlin. , in Kowik, I. & Körner S. (eds) Wild Urban Woodlands: New Perspectives for Urban Forestry. pp. 287-299. Springer.

Kowarik, I., 2005. Wild Urban Woodlands : Towards a Conceptual Framework New woodlands as a response to social and economic changes, in Kowik, I. & Körner S. (eds) Wild Urban Woodlands: New Perspectives for Urban Forestry. 1–32. Springer

Kowarik, I., 2011. Novel urban ecosystems, biodiversity, and conservation. Environ. Pollut. 159, 1974–1983. doi:10.1016/j.envpol.2011.02.022

Lindemann-Matthies, P., Junge, X., Matthies, D., 2009. The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. Biol. Conserv.

Lodge, A.H., East, B.C., Beckett, P., Freer-Smith, P.H., Taylor, G., 2000. Particulate pollution capture by urban trees: effect of species and windspeed. Glob. Chang. Biol. 6, 995–1003.

Lohr, V.I., 2013. Diversity in landscape plantings: Broader understanding and more teaching needed. Horttechnology 23, 126–129.

Louv, R., 2005. Last Child in the Woods: Saving Our Childern from Nature-deficit Disorder. Algonquin Books, Chapel Hill, NC.

Lozupone, C., Stomabaugh, J., Gordon, J., Jansson, J., Knight, R., 2012. Diversity, stability and resilience of the human gut microbiota. Nature 489, 220–230. doi:10.1038/nature11550.Diversity

Manfredo, M.J., Teel, T.L., Dietsch, A.M., 2015. Implications of human value shift and persistence for biodiversity conservation. Conserv. Biol. 30, 287–296. doi:10.1111/cobi.12619

Martens, D., Gutscher, H., Bauer, N., 2011. Walking in "wild" and "tended" urban forests: The impact on psychological well-being. J. Environ. Psychol. 31, 36–44.

Mathey, J., Arndt, T., Banse, J., Rink, D., 2016. Public perception of spontaneous vegetation on brownfields in urban areas—Results from surveys in Dresden and Leipzig (Germany). Urban For.

Urban Green. doi:10.1016/j.ufug.2016.10.007

Mathey, J., Röbler, S., Banse, J., Lehmann, I., Bräuer, A., 2015. Brownfields As an Element of Green Infrastructure for Implementing Ecosystem Services into Urban Areas. J. Urban Plan. Dev. 141(3), A4015001. doi:10.1061/(ASCE)UP.1943-5444.0000275

McClintock, N., Cooper, J. & Khandeshi, S. (2013) Assessing the potential contribution of vacant land to urban vegetable production and consumption in Oakland, California. Landscape and Urban Planning, 111, 46-58.

McPhearson, T., Kremer, P. & Hamstead, Z.A. (2013) Mapping ecosystem services in New York City: Applying a social–ecological approach in urban vacant land. Ecosystem Services, 5, 11-26.

Meffert, P.J., Marzluff, J.M., Dziock, F., 2012. Unintentional habitats: Value of a city for the wheatear (*Oenanthe oenanthe*). Landsc. Urban Plan. 108, 49–56. doi:10.1016/j.landurbplan.2012.07.013

Miller, J., Hobbs, R., 2002. Conservation where people live and work. Conserv. Biol. 16, 330–337.

Munshi-South, J., 2012. Urban landscape genetics: Canopy cover predicts gene flow between white-footed mouse (*Peromyscus leucopus*) populations in New York City. Mol. Ecol. 21, 1360–1378. doi:10.1111/j.1365-294X.2012.05476.x

Nassauer, J.I. (1995) Messy Ecosystems, Orderly Frames. Landscape Journal, 14, 161-170.

Nassauer, J.I., Raskin, J., 2014. Urban vacancy and land use legacies: A frontier for urban ecological research, design, and planning. Landsc. Urban Plan. 125, 245–253. doi:10.1016/j.landurbplan.2013.10.008

Odom Green, O., Garmestani, A.S., Albro, S., Ban, N.C., Berland, A., Burkman, C.E., Gardiner, M.M., Gunderson, L., Hopton, M.E., Schoon, M.L., Shuster, W.D., 2016. Adaptive governance to promote ecosystem services in urban green spaces. Urban Ecosyst. 19, 77–93. doi:10.1007/s11252-015-0476-2

Ossola, A., Hahs, A.K., Nash, M.A., Livesley, S.J., 2016. Habitat Complexity Enhances Comminution and Decomposition Processes in Urban Ecosystems. Ecosystems 19, 927–941. doi:10.1007/s10021-016-9976-z

Özgüner, H., Kendle, A.D., Bisgrove, R.J., 2007. Attitudes of landscape professionals towards naturalistic versus formal urban landscapes in the UK. Landsc. Urban Plan. 81, 34–45.

Pickett, S.T.A., Cadenasso, M.L., Childers, D.L., McDonnell, M.J., Zhou, W., 2016. Evolution and future of urban ecological science: ecology in , of , and for the city. Ecosyst. Heal. Sustain. 2, e01229. doi:10.1002/ehs2.1229

Ramalho, C.E., Laliberté, E., Poot, P., Hobbs, R.J., 2014. Complex effects of fragmentation on remnant woodland plant communities of a rapidly urbanizing biodiversity hotspot. Ecology 95, 2466–2478. doi:10.1890/13-1239.1

Reusch, T.B.H., Ehlers, A., Hämmerli, A., Worm, B., 2005. Ecosystem recovery after climatic extremes enhanced by genotypic diversity. Proc. Natl. Acad. Sci. 102, 2826–2831. doi:10.1073/pnas.0500008102

Robinson, S.L., Lundholm, J.T., 2012. Ecosystem services provided by urban spontaneous vegetation. Urban Ecosyst. 15, 545–557. doi:10.1007/s11252-012-0225-8

Rupprecht, C.D.D., Byrne, J.A., 2014. Informal urban green-space: Comparison of quantity and characteristics in Brisbane, Australia and Sapporo, Japan. PLoS One 9. doi:10.1371/journal.pone.0099784

Rupprecht, C.D.D., Byrne, J.A., Garden, J.G. & Hero, J.-M. (2015) Informal urban green space: A trilingual systematic review of its role for biodiversity and trends in the literature. Urban Forestry & Urban Greening, 14, 883-908.

Rupprecht, C.D.D., Byrne, J.A., Ueda, H., Lo, A.Y., 2015. "It"s real, not fake like a park': Residents' perception and use of informal urban green-space in Brisbane, Australia and Sapporo, Japan. Landsc. Urban Plan. 143, 205–218. doi:10.1016/j.landurbplan.2015.07.003

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. Ecosyst. Serv. 12, 1–15. doi:10.1016/j.ecoser.2014.12.007

Schnitzler, A., 2014. Towards a new European wilderness: Embracing unmanaged forest growth and the decolonisation of nature. Landsc. Urban Plan. 126, 74–80. doi:10.1016/j.landurbplan.2014.02.011

Southon, G.E., Jorgensen, A., Dunnett, N., Hoyle, H., Evans, K.L., 2017. Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. Landsc. Urban Plan. 158, 105–118. doi:10.1016/j.landurbplan.2016.08.003

Swanwick, C., 2009. Society's attitudes to and preferences for land and landscape. Land use policy 26, S62–S75. doi:10.1016/j.landusepol.2009.08.025

Thompson, K., Austin, K.C., Smith, R.M., Warren, P.H., Angold, P.G., Gaston, K.J., 2003. Urban domestic gardens (I): putting small-scale plant diversity in context. J. Veg. Sci. 14, 71–78.

Threlfall, C.G., Ossola, A., Hahs, A.K., Williams, N.S.G., Wilson, L., Livesley, S.J., 2016a. Variation in Vegetation Structure and Composition across Urban Green Space Types. Front. Ecol. Evol. 4, 1–12. doi:10.3389/fevo.2016.00066

Threlfall, C.G., Walker, K., Williams, N.S.G., Hahs, A.K., Mata, L., Stork, N., Livesley, S.J., 2015. The conservation value of urban green space habitats for Australian native bee communities. Biol. Conserv. 187, 240–248. doi:10.1016/j.biocon.2015.05.003

Threlfall, C.G., Williams, N.S.G., Hahs, A.K., Livesley, S.J., 2016b. Approaches to urban vegetation management and the impacts on urban bird and bat assemblages. Landsc. Urban Plan. 153, 28–39. doi:10.1016/j.landurbplan.2016.04.011

Tonietto, R., Fant, J., Ascher, J., Ellis, K., Larkin, D., 2011. A comparison of bee communities of Chicago green roofs, parks and prairies. Landsc. Urban Plan. doi:10.1016/j.landurbplan.2011.07.004

van den Berg, A.E., van Winsum-Westra, M., 2010. Manicured, romantic, or wild? The relation between need for structure and preferences for garden styles. Urban For. Urban Green. 9, 179–186. doi:10.1016/j.ufug.2010.01.006

van der Ree, R., Mcdonnell, M.J., Temby, I., Nelson, J., Whittingham, E., 2006. The establishment and dynamics of a recently established urban camp of flying foxes (*Pteropus poliocephalus*) outside their geographic range. J. Zool. 268, 177–185. doi:10.1111/j.1469-7998.2005.00005.x

Walsh, C.J., Webb, J.A., 2016. Interactive effects of urban stormwater drainage, land clearance, and flow regime on stream macroinvertebrate assemblages across a large metropolitan region. Freshw. Sci. 36, XXX–XXX. doi:10.1086/685105.

Wilson, A., Kendal, D. & Moore, J.L. (2016) Humans and Ornamental Plants: A Mutualism? Ecopsychology, 8, 257-263.

Wolch, J.R., Byrne, J. & Newell, J.P. (2014) Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough’. Landscape and Urban Planning, 125, 234-244.

Zeeman, B., McDonnell, M.J., Kendal, D., Morgan, J.W., 2017. Biotic homogenisation in an increasingly urbanised temperate grassland ecosystem. J. Veg. Sci.

Tables

Table 1 – A typology of wild spaces (shaded) distinguishing different kinds based on human intervention in community assembly processes (from spontaneous to managed), and composition in reference to historically known, naturally formed systems (from historic to novel). Wild spaces move from left to right along an axis of human involvement, such that some may be subject to initial management but subsequently unmanaged, in contrast to other spaces where ongoing management is required to maintain them in the desired state.

		← **Human involvement in community assembly** →		
		Spontaneous	↔	Managed
← **Composition reference** →	Historic ↕ Novel	Intact remnants	Ecological restorations	Ex-situ collections, Native gardens, cultural landscapes
		Degraded remnants	Revegetation	Informal parks and gardens
		Wastelands	Designed Meadows/ Abandoned lots	Formal parks and gardens, sports field

Table 2 - Spatial and temporal concepts or attributes related to wild spaces relevant to ecological and social thinking and future studies

Wild space attribute	**Example/description**
Spatial	
Size (m^2)	Small, large, fragmented etc
Arrangement or shape	Edge to area ratio
Distribution	Dispersed versus concentrated.
Connectivity	Isolated versus connected to other similar land covers
Physical location and context	Embedded within urban matrix or located on edge of city Types and extent of surrounding green spaces
Cultural context	Ethnicity, cultural diversity. Aesthetic and management norms
Demographic context	Population density, age, education level
Temporal	
Condition	Intact, degraded
Vegetation composition and structure	Successional state
Level of human intervention	Intentionally managed versus absence of management
Turnover	Change in identity of species
Immigration and extinction	The creation or removal of wild ecosystems from the landscape
Socioeconomic context	Advantaged vs disadvantaged. (e.g. can change with gentrification)
Social values context	Utilitarian vs Intrinsic and Non-use values for nature. This can influence the acceptability of wild spaces and how they change over time

Table 3 –Characteristics of different kinds of wild and non-wild spaces, and benefits they may provide.

Characteristic	Landscape type	Examples supply of characteristic/benefit	**Possible Benefit**
DIVERSITY			
Genetic diversity	Remnant	Can be very high due to high levels of sexual reproduction	Resilience (Reusch et al., 2005), Natural aesthetics, Can be preferred (Botzat et al., 2016; Kendal et al., 2008)
	Wasteland		
	Restoration	Depends on the size of the gene pool propagules collected from	
	Meadow		
	Amenity Park	Lower where cultivars are used e.g. (Lohr, 2013)	
	Sportsfield	Low	
Taxonomic diversity	Remnant	Ecosystem dependent	Resilience (Elmqvist et al., 2003), Naturalistic design (Özgüner et al., 2007), Increased preference (Lindemann-Matthies et al., 2009)
	Wasteland	Can be high due to large species pool e.g. (Kowarik, 2011)	
	Restoration	Ecosystem dependent, but often lower than reference system	
	Meadow	High (Hitchmough and de la Fleur, 2006)	
	Residential garden	Can be very high (Kendal et al., 2012b; Thompson et al., 2003)	
	Sportsfield	Low	
STRUCTURE			
Structural complexity	Remnant	Ecosystem dependent, but often high	Improved habitat for some species (Threlfall et al., 2016a), Preferred by some people (e.g. Harris et al, 2017, (van den Berg and van Winsum-Westra, 2010)
	Wasteland	Can be high e.g. (Kowarik, 2011)	
	Amenity Park	Usually low to provide perceptions of safety, mown turf for passive and active recreation	
	Sportsfield	Very low	
Tree canopy	Remnant/restored	High in forests and woodlands	Carbon sequestration (Dobbs et al., 2011), Shade/cooling (Dobbs et al., 2014), Pollution absorption (Lodge et al., 2000)
	Meadow	Low	
	Amenity Parks and gardens	Often high	
	Sportsfield	Low	
AESTHETICS			
Greenness	Remnant/ restored/ wasteland	Ecosystem dependent	Psychological restoration, increased preference (Kaufman and Lohr, 2004; Kendal et al., 2012a),
	Amenity Parks and gardens	Often high	
	Sportsfield	High	
Colour	Remnant/ restored/ wasteland	Ecosystem dependent, but often lower than horticultural landscapes	Increased preference/beauty (Goodness et al., 2016; Kendal et al., 2012a)
	Meadows	Often high (Dunnett and Hitchmough, 2008)	

	Residential Gardens	Often high (Kendal et al., 2012a)	
	Sportsfields	Low	
SOCIAL CHARACTERISTICS			
Surveillance	Remnant/ restored / wasteland	Ecosystem dependent, but can be low in structurally complex vegetation	Safety (Jorgensen et al., 2002)
	Meadow	Ecosystem dependent, but often high	
	Amenity Parks and gardens	Often high (Jorgensen et al., 2002)	
	Sportsfield	High	
Accessibility	Remnant/ restored	Location dependent, but access can be restricted (Gill et al., 2009)	Recreation potential (Haase et al., 2014), Physical health (Giles-Corti et al., 2005)
	Meadow	Location dependent, but often high when located in amenity parks (new Helen Hoyle ref)	
	Amenity Parks and gardens	Often high	
	Sportsfield	Often high	