frontiers in Built Environment

REVIEW
published: 24 March 2022
doi: 10.3389/fbuil.2022.769357

Ruderal Resilience: Applying a Ruderal Lens to Advance Multispecies Urbanism and Social-Ecological Systems Theory

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As global urbanization accelerates, cities have become increasingly complex and hybridized, and host to novel urban landscape forms such as informal greenspaces or novel ecosystems that support ruderal and spontaneous vegetation. Researchers have documented the ecosystem services or benefits these systems provide, as well as the tradeoffs or disservices associated with biotic globalization. Despite evidence of their co-benefits, fragmented knowledge and biased views of these novel ecological forms contributes to an underestimation of their social-ecological role and potential for serving as a model for resilient and nature-based urban design and planning. The social-ecological systems discourse has improved understanding of these emerging conditions, yet may benefit from an attunement to a multispecies perspective, an ecosystem-based approach to urban planning and governance that recognizes the interdependencies of humans and other organisms. This article explores the potential social-ecological role of ruderal landscapes in facilitating this transition, referred to as ruderal resilience, as well as recent research in SES and resilience theory that may help advance concepts such as multispecies urbanism and planning. The aim is to consider the potential for spontaneous ecological self-organization to serve as a device for reinvigorating relationships with urban ecological commons and advancing social-ecological systems theory.

Keywords: social-ecological urbanism, multispecies, ruderal vegetation, urban spontaneous vegetation, city planning, multispecies urbanism, resilience

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Specialty section:
This article was submitted to Urban Science, a section of the journal Frontiers in Built Environment

Received: *01 September 2021*
Accepted: *26 January 2022*
Published: *24 March 2022*

Citation:
Kennedy C (2022) Ruderal Resilience: Applying a Ruderal Lens to Advance Multispecies Urbanism and Social-Ecological Systems Theory. Front. Built Environ. 8:769357. doi: 10.3389/fbuil.2022.769357

INTRODUCTION

Urbanization has accelerated rapidly across the globe, driving elevated levels of climate risk and altered ecological processes, declining health and well-being, and contributes to the rise of new urban landscape forms (McKinney, 2006, 2008; Seto 2012; Gómez-Baggethun et al., 2013; Elmqvist et al., 2021; IPCC 2021). As a result, cities are complex urban ecological systems and increasingly comprised of novel ecosystems and ruderal ecologies, which are self-assembling biotic communities that emerge in sites of disturbance with little or no human management (Tredici 2010; Morse et al., 2014; Rupprecht et al., 2014; Ahern 2016; Higgs 2017; Newman et al., 2018; Threlfall and Kendall 2018). Over the past decade, researchers find these systems offer critical ecosystem services, or benefits provided to humans and other organisms, while simultaneously presenting new challenges and disservices that highlight the consequence of biotic globalization

(Davis 2003; Robinson and Lundholm 2012). The study of social-ecological systems (SES) has offered new ways to understand these emerging conditions, aiding researchers in identifying how novel and ruderal systems are intertwined and interact with SES within a city (Reyers et al., 2018). Yet, despite mounting evidence of their social-ecological role, they continue to be underutilized or managed through design practices that commonly privilege a human-centric vision of urban design and planning (Valéry 2013; Douglass 2015; Rupprecht et al., 2015; Ziter et al., 2017; Keeler et al., 2019; Yang et al., 2019). At the same time many resilience theorists and mainstream ecologists ignore the role of humans, cultural systems, or Indigenous knowledge within SES when analyzing urban environments (Berkes et al., 2003; Wilkinson 2012). Scholars point to how this can result in an incomplete understanding of complex SES that is not inclusive of diverse stakeholder experience and needs, and may not adequately address issues of urban resilience or environmental justice long-term (Millard 2004; Hobbs et al., 2011; Paperson 2014; Rupprecht et al., 2020; Chu and Cannon 2021).

In response, researchers advocate for a fundamental rethinking of sustainability to achieve what Houston et al. (2018) describe as "multispecies flourishing," or the envisioning of social-ecological futures that recognize the wellbeing of humans and other species are interdependent (Miller et al., 2020). Rupprecht et al. (2020) further propose the concept of "multispecies sustainability," highlighting the insufficiency of current sustainability frameworks which they argue ignore "interspecies relations" and may prevent society from seriously addressing the global climate crisis, a decline in biodiversity, and the urgent need to decarbonize economies worldwide. In cities, because of their recent proliferation, novel and ruderal ecologies present both a challenge and opportunity to envision "more-than-human" relationships, policies, and practices, and to reconsider reductionist approaches to urban planning and land management. As some of the most visible landscapes in cities, ranging from vacant lots to disturbed waterways, scholars emphasize the value of examining ruderal systems because they present a unique meeting point for considering the impacts of urbanization and socio-ecological injustices, while also showcasing ecological functions, traits, and adaptive capacities that may be useful in conceiving of effective and equitable approaches to urban climate adaptation (Thompson and McCarthy 2008; Riley et al., 2018a; Evers et al., 2018; Kwok 2018). While this alone may not be sufficient to address the critical degradation of the earth system, a ruderal perspective may present one strategy among many to advance understandings of cities as complex social-ecological systems.

The aim of this article is to explore the social-ecological role of ruderal ecologies within cities, and to consider how they may aid in advancing multispecies approaches to urban planning and governance. To accomplish this, the article synthesizes emerging literature on SES theory, multispecies urbanism, novel ecosystems and urban systems theory to explore potentials for reframing conventional resiliency thinking to account for the increasingly complex and novel nature of urban environments, which is referred to as "ruderal resilience." Throughout, emerging scholarship on multispecies studies, as well as Bettina Stoetzer's (2018) method for applying a ruderal perspective is utilized to consider the evolution of modern infrastructure systems and ontologies as well as their degradation. In her analysis of informal greenspaces in Berlin, Stoetzer explains a ruderal lens may allow researchers to "combine an analysis of ruins and their emerging ecologies with questions of urban social justice . . . " (pg. 299). The first section explores recent histories and new formulations of SES theory and discourse. The next sections consider the historical context and emerging conditions of cities, and the final concluding sections further explore the notion of ruderal resilience and examine the potential of multispecies urbanism and planning to inform future conceptions of SES theory and practice. Although examples of ruderal systems can be diverse, we focus particularly on urban plant communities and associated landscapes, in part because plants are the most abundant lifeform on the planet and urban vegetation can be influential in shaping city dwellers' perceptions of nature, improving well-being and social cohesion, and people's connection with the natural world more generally (Jorgensen and Gobster 2010; Weber et al., 2014; Vega and Schläpfer-Miller 2021). Finally, although we consider urban environments within a global context, the author acknowledges a particular emphasis on the experience of US cities and urban planning and design policies.

MATERIALS AND METHODS

Utilizing a narrative review approach, the article integrates extant literature on social-ecological systems theory, ruderal and novel ecosystems, and urban systems theory, primarily from 2000 onwards. To initiate the review, several researchers active in the field of urban ecology and resilience research were identified, particularly with experience in social-ecological systems analysis. The list of researchers contacted was informed by previous unsystematic literature searches and exchanges with colleagues working in these fields. Next, key search terms were identified to address gaps in literature provided and to search for additional theoretical frameworks, empirical research studies, and writings. A literature search was conducted on the main full-text academic databases including Scopus, Google Scholar and RefSeek. The primary aim was to synthesize emerging research in addition to exemplary studies identified by researchers in the field that examine the evolution of cities as complex systems and how Modern ontologies of planning and resource management may drive nature-culture divides. In Section *Exploring the Social-Ecological Systems Discourse*, Colding and Barthel's (2019) synthesis review, the work of Folke (2016), as well as relevant scholarship in SES were utilized to examine how SES theory has informed analysis of urban systems in Europe and the US. We further searched for studies and theoretical analysis for how SES theory has been leveraged to advance conceptions of urban resilience, planning and resilience thinking in the US, and other parts of the world. Sections *Cities as Human Domains* and *Cities as Patchy, Ruderal and Hybrid Social-Ecological Systems* situate both historic and contemporary perspectives on the trajectory of urban planning,

TABLE 1 | A comparison of conventional resilience thinking and ruderal resilience.

Resilience concept	Conventional view	Ruderal view
Disturbance	Resilience as a measure of a system's capacity to absorb disturbance in advance of regime change. Aim is to retain essentially the same function, structure, and feedbacks. Folke (2016)	The capacity of a system to absorb, embrace and leverage disturbance to form new, metastable conditions in response to new mixes of species or environmental conditions. Disturbance is viewed as an affordance. Higgs (2017)
Adaptation	A process of intentional or deliberate change, often in reaction to stress or external stimuli. Adaptability is "the capacity of actors in a system to influence resilience" Walker et al. (2004)	Rapid, responsive, or flexible adaptive capacity to disturbance and human activity. Ability to hybridize, seek interdependencies between human/nonhumans, and evolve in a relatively short time period and across multiple scales. Donihue and Lambert (2015), Elmqvist et al. (2019)
Transformation	The ability to cross thresholds and move social-ecological systems into new configurations and unknown development trajectories. Feola (2015)	The ability to cross an ecological threshold and to form self-sustaining and self-organized social-ecological systems. SES can provide benefits to both humans and nonhumans, and are designed to be regenerative or restorative. Developmental pathway does not seek historical continuity. Morse et al. (2014), Evers et al. (2018)
Co-Management/ Stewardship	Stewardship in the service of human interests, or benefits to nature that are valued by people, often with a specific aesthetic and use-value approach. Maintaining systems for human consumption or use. Elmqvist et al. (2013)	Biocultural stewardship approaches that support care and co-management of ecosystems whether historical, hybrid, or novel. Inclusion of indigenous practices, cultural landscapes, and historic issues of inequity and oppression. Consideration of self-assembling systems that require little to no management. Threlfall and Kendal (2018), McMillen et al. (2020), Higgs (2012)

conservation and resource management in the Global North, and new understandings of novel and ruderal ecosystems in urban areas. In the case of ruderal ecosystems, the terms "urban spontaneous vegetation," "informal greenspace," "ruderal ecology," and "novel ecosystem" were searched for in either the title, abstract, or keywords of peer-reviewed articles. In particular the work of Mark A. Davis (2006, 2011, 2015), David del Tredici (2010), Anna Tsing (2013, 2019) and Matthew Gandy (2013) provide a conceptual framing to understand the evolution of fields such as invasion ecology and how this informs current planning and management approaches. Further, systematic reviews such as Evers et al. (2018), and studies on urban adaptation (Donihue and Lambert 2015; McDonnell and Hahs 2015) provide a useful synthesis to understand the benefits, functions, and disservices of novel ecosystems, and was influential in developing the concept of "ruderal resilience." Section *Cities as Places for Multispecies Flourishing*, summarizes key perspectives in the development of multispecies thinking and biocultural stewardship and their application to the fields of urban planning and design. The terms "multispecies," "multispecies urbanism" and "multispecies planning," "biocultural stewardship," and "biocultural" were searched for in the title, abstract, or keywords. The work of Houston et al. (2018) and Rupprecht et al. (2020), as well as non-western and Indigenous perspectives (e.g., Salmón 2000; Kimmerer 2011) were utilized to consider how multispecies thinking may inform urban planning, stewardship and governance. Finally, in Section *Moving Toward Ruderal Resilience* we further articulate the notion of "ruderal resilience," connecting previously discussed literature and relevant case studies. **Table 1** summarizes the key texts used to discuss similarities and differences between a conventional and ruderal approach to resilience thinking. Throughout, the review draws from Stoetzer's (2018) application of a "ruderal lens" to highlight both the potential and challenge of examining the edges, margins, and intersection of multiple SES within cities, and as a device to interrogate divisions between ecocentric and human-centered thinking.

EXPLORING THE SOCIAL-ECOLOGICAL SYSTEMS DISCOURSE

Social-ecological systems (SES) theory is a framework to examine the interconnections between people and nature, highlighting the biophysical and social factors that interact and drive environmental and social change (Wilkinson 2012; Anderies 2014). Since its first use in the early 1970s, the study of SES is framed as an interdisciplinary endeavor that aims to apply systems theory to answer critical questions about the interactions between social and ecological systems (Ban et al., 2013; Fabinyi 2014; Colding and Barthel 2019). The kinds of SES studied vary in terms of their spatial, temporal, and organizational scales, but are considered to be adaptive, resilient and complex systems through which multiple feedbacks and flows of natural resources are regulated (Frank, Delano, Caniglia 2017; Reyers et al., 2018). SES theory helps practitioners and researchers structure the analysis of complex processes within SES, encouraging a consideration of both biophysical and human-induced relations and states. Although SES theory can apply to many aspects of the one planetary system we cohabitate, this review is focused primarily on SES within urban areas with a particular focus on cities in the US, and how approaches to planning, governance and urban development are co-produced and shaped by SES.

C.S. Holling's (1973) work in systems ecology is noted as a crucial turning point in SES theory because it proposed a different way of thinking about ecosystem dynamics and change. For example, Holling's analysis finds ecosystems do not reach an optimal state of "balance" but rather undergo a dynamic process of change and adaptation to ongoing disturbances within an environment (Ratzlaff 1970). This was integral to the development of resilience theory, because it began to articulate the capacity of ecosystems to respond to and absorb change, and also how this occurs at varying scales or "stability domains." This was considered foundational at the time because it challenged the popular discourse of "ecological balance" within the field of ecology, an assumption that ecological systems are linear or static, and able to be restored to some timeless "normal" state (Phillips 2003). The early conceptualization of resilience thus provides a framework to understand systems as complex and adaptive, where resilience refers to the capacity of a system to handle ongoing disturbance and shocks (to be adaptive), while retaining the function, form, and feedbacks that define the system's identity (to be resilient) (Folke 2016). The notion of adaptation or adaptability is a key component, which is the capacity of a system to anticipate and respond to change, and thus to influence resilience. While resilience thinking emphasizes that systems will continually change and adapt, they also must at times transform through the alteration of SES structures or feedbacks (Görg et al., 2017).

More recently, researchers have stressed the need to understand resilience in the context of ongoing urbanization. Elmqvist et al. (2019) for instance highlight the concept of "urban resilience," which argues for a consideration of complexity in understanding the resilience of multiple system interactions and feedbacks at different scales within an urban area. Rather than assume multiple stable states, they advocate for an understanding of transformation that position urban systems as "having multiple possible developmental pathways or trajectories" (p. 270). Resilience is then the capacity of a system to strengthen a specific pathway, and to cope and adapt to disturbances and uncertainty while maintaining functions along this path. The pathway can be widened (e.g., strengthened) through directed transformations, or narrowed and focused through an abrupt transformation when immediate action is needed.

Resilience thinking is central to SES theory, which recognizes the inherent interdependence of human and natural systems accounting for the social, political and economic dimensions when examining urban and environmental systems (Wilkinson 2012). Researchers use the term social-ecological resilience to assess and measure the capacity of SES to be resilient and adaptive. Berkes et al. (1998) used this refined understanding to develop the concept of adaptive management which provides a framework to assist practitioners, resource managers and others in managing the feedback of complex systems to promote adaptive sustainable development goals and governance (Olsson et al., 2004). The framework advocates for democratic forms of decision making and to assess the best means to measure and promote social-ecological resilience (Berkes 2009).

The SES discourse has since influenced research in both the natural and social sciences to understand cities and urban dynamics. One area is concerned with the biophysical patterns of natural systems within urban environments, how they are influenced by people, and environmental interactions across geographies and scales (e.g., urban climate and soils, vegetation and biodiversity, among other factors) (Anderson and Elmqvist, 2012; Grimm et al., 2000; Wu 2014; Nassauer et al., 2014). Other researchers are studying the spatiotemporal patterns of cities, how land uses and urban forms change over time, how this influences the "urban metabolism" of cities, as well as the long-term impacts of resource consumption, infrastructure, management policy, or social dynamics within cities (Pacione 2009; Kennedy 2011; Da Cunha et al., 2012). Social scientists also examine the impacts of segregation and fragmentation of human communities based on demographic features, as well as opportunities to improve social wellbeing, mobility, and overall planning and sustainability (Lin and Robinson 2012). Urban ecologists and others also apply and frame SES theory to quantify and assess the urban ecosystems services within urban areas, which are the benefits ecosystems provide such as fresh water, food, carbon sequestration or climate regulation (Wu 2014; Kremer et al., 2016; Locke and McPhearson, 2018).

Over the past several decades the social-ecological systems (SES) discourse has evolved. For instance, advances in commons theory and political ecology have since advocated for new distributed governance concepts that account for inter and intra-scale decision making, as well as unpredictability and change (Bäckstrand, 2006; Armitage, 2007; Huitema et al., 2009). The SES framework has also been applied to examine systemic response to challenges like climate change and to understand urban systems, stressing the importance of integrating social-bio-geophysical frameworks in examining cities in terms of their spatial, temporal and organizational scales and cross-interactions (Cole, Oliver, and Robinson 2013; Frank et al., 2017). More recently, researchers highlight the importance of technological systems, advocating for a "SETS-integrated" approach that views the design, maintenance and evolution of infrastructure systems as inseparable from human well-being (McPhearson et al., 2016; Grabowski et al., 2017; Chester 2019). Building on the work of Monstadt (2009), and Pandit et al.'s (2017) notion of infrastructure ecosystems, this perspective stresses the need to consider how the impacts to infrastructure systems directly impact human systems (loss of life or property, economic impacts) and how a SETS-integrated approach can increase co-benefits, reduce costs, and improve operation. Practitioners and researchers have also applied SES theory to conceptualize social-ecological urbanism (SEU), an approach to guide urban planning and design that accounts for the interconnections and conflicts between ecological and social-cultural systems, leveraging design to plan for ongoing change and adaptation and thus building resilience (Bartel et al., 2013). Barthel et al.'s (2013) work with researchers at the Stockholm Resilience Center provides some of the first guiding principles for SEU. In looking at the case of the Albano Resilient Campus at Stockholm University they explain that change and diversity can be a strategy for adaptive management, highlighting the importance of self-organization and place-based learning, as well as synergies between social, ecological, economic and cultural urban system services (Nadasdy 2007).

SES theory has also been used to articulate new conceptions of urban ecological resilience and nature-based solutions, or ecosystem-based interventions that aim to address economic, social and ecological challenges (Pickett et al., 2020; Randrup et al., 2020). Nature-based solutions encompass a wide range of strategies but often involve the coupling of social and biophysical factors, stressing the interdependence of people and urban nature (Frantzeskaki et al., 2019). The NBS concept draws from the development of ecosystem-based approaches to natural resource management, such as ecosystem-based adaptation (EbA), which seek the long-term sustainability of ecosystem functions and services and draw from traditional practices such as holism or holistic planning (Convention on Biological Diversity 2000; Luchkova 2011; Droz 2020). Yet, in spite of their popularization, some researchers note that SES discourse often fails to integrate ecological perspectives, with many studies ignoring recent advances in ecology or the natural sciences, and lack of a biophysical analysis (Epstein et al., 2013). For example, Childers et al. (2019) propose the concept of urban ecological infrastructure (UEI), an inclusive framing of both infrastructure and ecological systems to expand conceptions of forms in the built environment such as "hybrid infrastructure" or "accidental UEI" to bridge silos between urban scientists and practitioners. Still, other researchers advocate for a "traits-based framework" that considers the emerging functions and characteristics of urban ecological systems in addition to ES (Andersson, et al., 2021). The following sections explore some of the historical context for why this integrative gap persists today.

CITIES AS HUMAN DOMAINS

Although our evolution from hunter-gatherer societies to complex megalopolises has taken many directions, cities are still largely viewed as a human terrain of social-cultural relations that prioritize human infrastructures over ones that would benefit multiple species (Davies and Riach 2019). Some scholars describe this as a kind of human or urban exceptionalism that is particularly prevalent in Western cultures, and points to a need to understand how this has informed SES theory and urban planning discourse (Laukyte 2016). In the early modern era Western cities were largely designed in the midst of colonial conquest and imperialism, featuring utopic spaces to showcase the fruits of the Enlightenment and Renaissance (Bahrainy and Bakhtiar 2016). In contrast, in Asia and other parts of the Global South, urban planning was often influenced by other political ideologies, spiritual traditions or cosmologies such as Confucianism, Taoism, Buddhism, which stress the importance of harmony and interconnectedness with nature, commonly structuring cities around the design of traditional gardens, temples, and other sacred sites (Douglass 2015; Tceluiko 2019).

In the Global North, industrialization in the 19th century, as well as public health crises drove a movement to preserve open breathing space for public health, sometimes referred to as the garden city concept which popularized the creation of public parks and large boulevards (Fishman 1982; Schuyler 1988). However, by the 20th century, the automobile began to reshape city life, with global conflicts bringing austerity to some and postwar prosperity to others (Caro 1974; Safdie, Kohn, McKnight 1997). The emergence of modernist urban design and planning around the same time began to champion a mechanistic view of cities, positioning urban regions as efficient machines and spatial units to be zoned according to use or function (Peponis 1989). This would later inform concepts such as Metabolism, a modernist architecture movement which advocated for the development of megastructures inspired by organic growth, or living cells (Kennedy et al., 2011). In the latter half of the 20th century, post-war reconstructionist movements like New Brutalism organized cities into two parts: essential and nonessential, further emphasizing a division between private and public spaces (Herron, 1966; Banz 1970; Schalk 2014; Angelidou 2015). Conversely, concepts such as New Urbanism sought a neo-traditional approach that focused on simulating a village-like community and mixed-use streets, while more recently, the just city concept, smart growth, and sustainable urban design seek to confront social, ecological and political challenges (Krieger 1974; Alexander et al., 1987; Platt 1994; Moughtin 1996; Marshall 2008). SES discourse has advanced our understanding of these historical contexts in many ways, but has yet to fully recognize the critical role of nonhumans or traditional ecological knowledge in the historical trajectory and contemporary formation of cities today (Glaser et al., 2008; Childers et al., 2015; Jon 2020; Betz and Coley 2021).

The development of environmental planning is a similar case. Since the start of the modern era, many US cities have launched urban greening efforts that range from large-scale conservation programs to the installation of green infrastructure, or policies to improve public health (Daniels 2009). Many of these approaches are influenced by fields such as conservation ecology which Sarkar (2005) points out, is "fundamentally an expression of human values" (pg. 80). For example, in the US the progressive era of environmental planning was largely focused on the development of urban parks and playgrounds, and the preservation of nature for people to admire from afar (Schulyer 1988). From the 1920's–1960's many cities began to consider a regional perspective championed by landscape architect Ian McHarg (1969), which applies the emerging discourse of ecology and natural science to federal and regional policies and protections of wilderness areas (Randolph 2003). Yet by the 1960's, the consequence of unregulated consumption refocused efforts in the U.S. on large-scale pollution clean-up programs, much of which was dismantled in the 1980's as deregulation paved the way for industry-led policies promoting "sustainable economic growth" for human benefit, which remains a dominant approach today (Beder 1998; Shabecoff 2003). Although well-intended, these practices focus primarily on protecting and preserving natural resources, not necessarily because of their intrinsic value as Soulé (1985) would suggest, but rather to ensure humans can consume or experience these resources in the future. Here, urban nature is framed as a commodity and environmental planning emerges as a neoliberal endeavor, reduced to a set of best practices premised on technical rationality (Brand 2007).

Yet despite this, several efforts, particularly within the field of landscape ecology, or the study of the interactions and spatial distribution of ecosystems, began to call for more holistic planning in which the urban landscape is considered as interconnected with a city (Forman and Godron 1981; Naveh 2000). In the 1980's, new theories of landscape urbanism were introduced emphasizing the idea that cities are most effectively designed and planned through the lens of landscapes (Waldheim 2006). This entails first understanding the social and ecological systems that comprise an urban environment, and planning cities around the idea that people and nature can and should coexist. In more recent years, landscape architects and planners have advocated for the idea of "landscape ecological urbanism" which draws from Mohsen Mostafavi's (2010) notion of ecological urbanism, to envision urban planning and design practices that can adapt and transcend social-ecological challenges with the goal of increasing ecosystem services and allowing for multiple functions and structures to exist simultaneously. Since its popularization in the 1990's, several examples have emerged ranging from the design of Freshkills Park and the High Line project in New York City, to the sponge city concept in Asia (Steiner 2011).

Restoration ecology, or the practice of mitigating the damage to natural habitats, present another salient example (Gobster 2010). While well-intentioned, efforts to restore "native" biodiversity are often rooted in a human-centered approach to land management influenced by the field of invasion biology, which focuses on the study of the adverse effects of "invasive alien species" on "native" plants, animals, and other organisms (Davis 2006; Chew and Hamilton 2010; Barrett 2011; Larson 2011; Orion 2015). Mark A. Davis (2006), a historian of invasion biology, notes the work of Charles Elton (1958) and 1964 International Union of Biological Sciences symposium as important milestones in the field which continues to have a large influence on regional and international conservation programs, and legal frameworks used to authorize spending on invasive management. By the 1990's scholarship in the field had grown exponentially with many studies focused on the impacts of biodiversity on island nations or agriculture, often used to support restoration agendas that do not necessarily reflect recent theories of resilience and adaptation (Davis et al., 2011). Further, the majority of invasive control measures are for the benefit of human communities (e.g., industrial agriculture), enabling carbon-intensive practices and herbicide application that may not be effective long-term, and is also damaging to ecological communities (Lidström and West 2017; Davis 2009; Orion 2015; D'Antonio and Meyerson 2002; Longcore et al., 1997). While the management of certain species is important, the majority of global analyses have not been able to empirically conclude that alien species invasions have resulted in a significant extinction threat (McKinney 2002; Aronson et al., 2014; Davis 2015; Pearce 2016). Rather it is more likely that climate or human activities impact species diversity and abundance, and has more significant implications for economic, social, or ecological systems (Didham et al., 2005; Thomas 2013; Pearce 2016; Essl et al., 2020).

Lidström et al. (2016) in particular highlights how the discourse of invasion can influence our perception of urban environments, noting the pervasive use of violent and war-like rhetoric to connote alien species as abnormal and support an assumption that the decline of one species would result in ecosystem collapse. The attempt to recreate historical continuity, or bringing ecosystems back to some desired state is nearly impossible given natural systems are dynamic and adaptive, in addition to the ongoing impact of human activities (Gould 1998; Davis 2012). In many areas of the world humans have been in relation to landscapes for centuries, or what theorists term "cultural landscapes" to describe landscapes altered by humans, recognizing the emergence of agricultural and maintenance practices that can often improve the ecological functions, regulating services, and cultural worth of the system (Plieninger et al., 2014; Tieskens et al., 2017; Maier et al., 2021). Yet despite examples of human coexistence, the dominant narrative of invasion continues to reinscribe a "good" versus "bad" binary that can obscure the real issue of human impact on the earth and ignores the complexity and evolution of urban environments (Valéry, Fritz, and Lefeuvre 2013). This can have a large influence on our attitudes and beliefs surrounding urban ecosystems, positioning wild untouched pastoral landscapes as the ultimate ideal and may distance urban dwellers from the lifeworlds of species they regularly encounter (Anderson 2009; Mastnak et al., 2014; Lidström et al., 2016). In response, restoration ecologists like Eric Higgs (2012) suggest a need to recognize the important and emerging role of hybrid and novel ecosystems, rather than attempt to control and restore them long-term. He advocates for management strategies such as regeneration ecology and wild design that offer a more nuanced view of ecosystem adaptation, alongside traditional management methods.

CITIES AS PATCHY, RUDERAL AND HYBRID SOCIAL-ECOLOGICAL SYSTEMS

As cities evolve and expand globally, new paradigms of urbanization are emerging, which understand urban areas as complex social-ecological systems that are multi-scale and "patchy" (McHale et al., 2015). As Steward Pickett and others (2020) point out, cities are no longer a grouping of homogenous land classes but rather hybridized systems where human-nature interactions drive and define spatial organization, change, and disturbance (Hou 2006). Hybridity here is not concerned with how technology is intertwined with city life (e.g., smart cities), but rather how social and biophysical elements within cities and urban landscapes are co-produced. Marshall et al.'s (2020) update on the concept of patch dynamics and urban mosaics is useful here, offering a new understanding of the biophysical structure of urban environments as hybrid heterogeneous collections of buildings, vegetation, paved surfaces, and soil that they term "patches." Zhou et al. (2021) and others conceptualize this as a "meta-city," or the notion that cities are intimately connected complex systems that are adapting to ongoing conditions (McGrath and Pickett 2011).

The SES discourse is helpful in understanding this in so far as it makes visible particular connections and recommendations for how to organize forms of governance or planning. Yet a number of researchers point out this application is limited considering new expressions and evolutions of cities (Görg et al., 2017). Ingalls (2017) for instance underscores the need to better articulate the spatial dimensions of SES, while Haase et al. (2014) notes that not all cities will expand in the future and may in fact actually shrink, requiring new models and analysis. In tandem, the impacts of industrialization and disinvestment in social programs increasingly make visible new urban forms like abandoned lots and railways, polluted brownfields, and highway infrastructure (Chapin and Starfield 1997; Morse et al., 2014). Gilles Clément (2016) describes these as a "third landscape," or what Matthew Gandy (2013) calls "ecological refugia," detailing emergent conceptualizations of urban wastelands, voids, non-spaces, or marginal ecologies which now define landscapes in cities worldwide, yet continue to be understudied within SES discourse (Anderson 2009; Bonthoux et al., 2019). Advancing SES theory to understand how these new urban forms operate and contribute to the social-ecological resilience of cities is critical. This first requires a consideration of the biophysical, ecological, and biocultural dimensions of urban spontaneous vegetation, and ruderal ecologies.

Ruderal ecologies are closely related to the concept of novel ecosystems but are more commonly found in urban areas where the impacts of human disturbance are felt more widely such as waste grounds, post-industrial land, or after an extreme event (Anderson 2009; Mabey and Sinclair 2010; Lachmund 2013; Gandy 2016). Ruderal vegetation is often the first sign of secondary ecological succession, and the plants and organisms found within these systems exhibit a disturbance-tolerating life strategy, enabling rapid recovery (Tredici 2010). The term ruderal, which comes from the Latin word, rudus, or rubble, was first popularized by ecologists who were studying the arrival of new plant communities in the ruins of a post-WWII Berlin. In studying the bombed-out craters left behind by several years of conflict, scientists like Herbert Sukopp discovered plants from halfway around the world that hitched a ride on planes, boats, and the boots of soldiers, inspiring some of the first studies within the field of urban ecology (Sukopp and Werner 1983; Lachmund 2003).

Over the past decade, ecologists have increasingly documented the ecosystem services novel and ruderal ecologies provide (Millard 2004; McPhearson et al., 2013). These include regulating the urban heat island, stormwater absorption, erosion control and river bank stabilization, creating a habitat for wildlife, carbon sequestration, cultural and recreational uses, among others (Tredici 2010; Evers et al., 2018). Some research even points to ruderal vegetation improving habitat provisioning for invertebrates and bird species, an increase in plant diversity and richness in areas like lawns and managed urban greenspaces, and has been linked to increased pollinator activity and higher levels of microclimate regulation (Robinson and Lundholm 2012; Turo and Gardiner 2019). Researchers also highlight the social-ecological role that informal greenspaces, vacant lots and ruderal areas provide for food provisioning and vegetable production, cultural and social uses, novel forms of stewardship, and how they function as key sites for foraging and social connection (Carne 1994; McClintock et al., 2013; McLain et al., 2014). Anderson and Minor (2017; 2020) similarly find that ruderal sites like vacant lots can offer economic benefits to city dwellers through the provision of ecosystem services like stormwater retention or bioremediation of sites that have been contaminated with lead, resulting in public health savings. Ruderal areas can also provide a needed refuge for urban communities providing psychological and health benefits, opportunities for education and research, unstructured play for youth, and can promote an improved relationship with urban nature (Threlfall and Kendal 2018).

Ruderal ecologies are also expressions of spontaneous ecological self-organization in cities, as well as novel forms of adaptation and ecological traits related in part to what researchers describe as "rapid urban evolution," or the accelerated adaptation of plants and animals to urban environments (Sanderson 2008; Donihue and Lambert 2015; Johnson et al., 2015; Kerstes et al., 2019). The term synurbization is specifically used when describing the adaptation of animals to urban environments. While ecologists once thought evolutionary processes would take centuries, they are now observing certain animals and plants exhibiting greater phenotypic or behavioral plasticity, or changes to their genetic traits or behavior within decades (Malik et al., 2012; McDonnel and Hahs 2015; Winchell et al., 2016). For example, some ruderal species are adept at facilitating forms of bioremediation, a process by which organisms consume and break down environmental pollutants (Porebska and Ostrowska 1999; Conesa and Faz 2011). Ruderal plant species are also observed to showcase a range of genetic divergences and ability to hybridize. Hybrid sunflowers (*Helianthus annuus L.*) for instance have evolved to adapt to drought conditions and salty soils, while white footed mice in NYC have been shown to demonstrate place-dependent trait changes that favor immune response, metabolism, and spermatogenesis, in response to habitat fragmentation and urbanization (Munshi-South and Kharchenko 2010; Donihue and Lambert 2015). Additionally, ruderal plants are often stress-tolerant, exhibit rapid growth and reproductive cycles, high seed yields and can take root in challenging soils (Beerling 1991; Crawley 2004; Chen et al., 2014; Williams et al., 2015; Chai et al., 2016; Cordeau et al., 2017; Ksiazek-Mikenas and Köhler 2018). And they may also increase the biodiversity of an area including plant diversity, arthropod and insect diversity, avian activity, and bird species richness (Adams 1994; Marzluff and Rodewald 2008; Rupprecht et al., 2014; Riley et al., 2018b; Kalarus et al., 2019; Zhang et al., 2020).

In large cosmopolitan cities, ruderal ecologies are now a common feature of the urban environment (**Figure 1**). Vacant land, where a large majority of ruderal ecologies are located, comprises on average 12.5–15% of the total land area for U.S. cities (with populations over 200,000) (Newman et al., 2016). In New York City (NYC) urban vacant land accounts for 9.7% of total land area (or 20,000 acres), yet for the most part is underutilized, heavily maintained, or inaccessible (Bowman and Pagano, 2000; Nassauer and Raskin 2014; Kremer et al., 2016). To better understand the social–ecological value of these sites, Kremer et al. (2016) conducted a study to assess the spatial distribution, ecosystem services and social-ecological role of

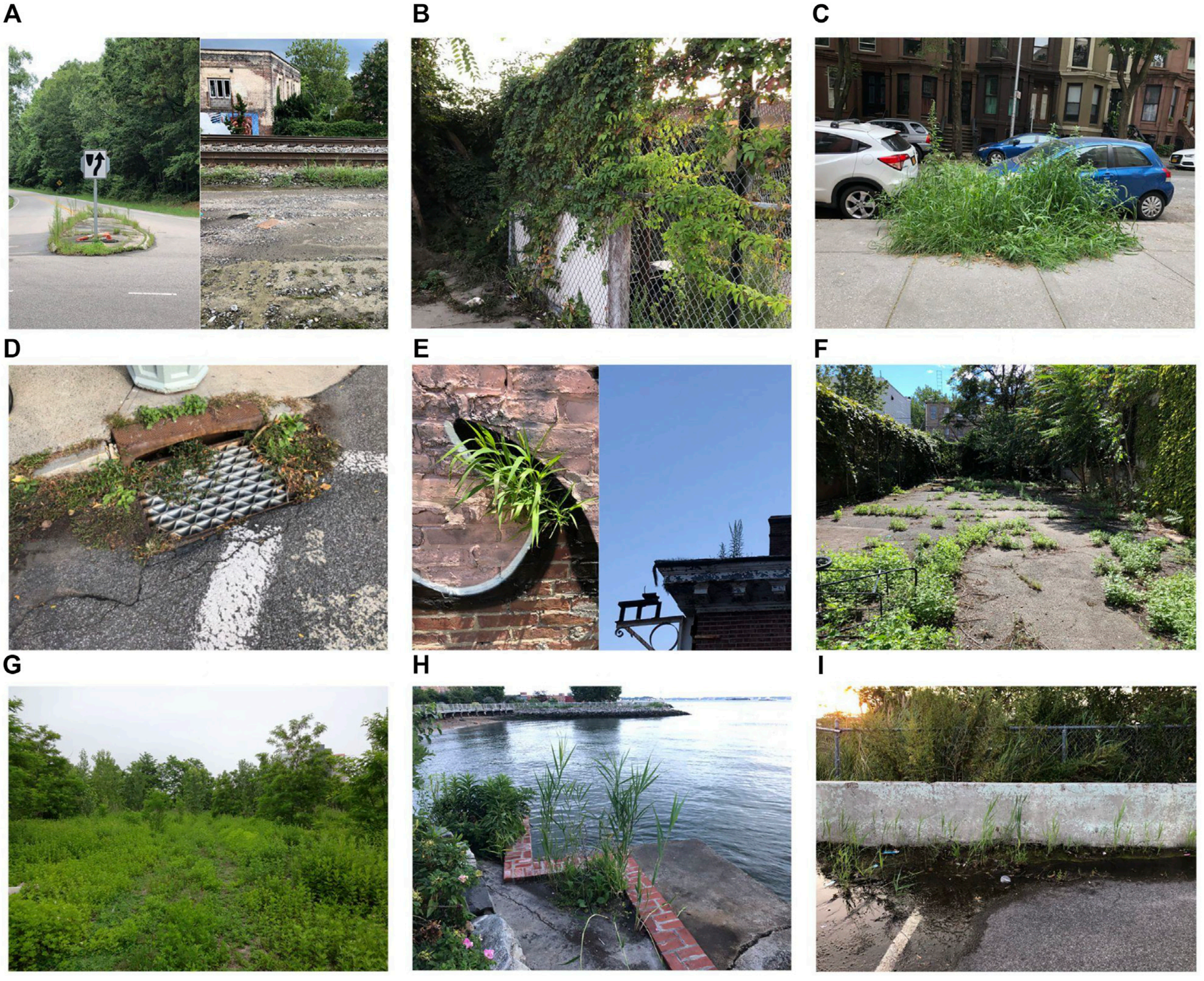

FIGURE 1 | Common ruderal habitats in New York City. **(A)** Ruderway, urban plant communities located near roadways or transportation corridors (Monocots, annuals, herbaceous perennials, deciduous shrubs, semi evergreen vines, and deciduous wood vines); **(B)** Vertical Support Structures, located on fences, gates, walls and other human-made infrastructures (semi evergreen vines, deciduous wood vines, and climbing shrubs); **(C)** Urban Fissures, urban plants that thrive in the gaps, holes, cracks, rifts and openings of impervious surfaces (herbaceous perennials, monocots, prostrate, summer annuals, herbaceous biennial, and Therophytes); **(D)** Storm Drain Ruderal Basins, found in and around storm drainage systems (herbaceous perennials, prostrate, and summer annuals); **(E)** Urban Epiphytes, urban plants that grow on, out of, or around rooftops and vertical infrastructures (Winter or summer annuals); **(F)** Living Lots, vacant or underutilized land parcels that support urban plant communities (Wood dicots, multi stemmed shrubs, summer and winter annual, herbaceous perennial, deciduous tree, and monocots); **(G)** Postindustrial Meadow or Forest, disturbed postindustrial landscapes (Deciduous trees, conifer, monocots, annual, herbaceous perennial, winter and summer annuals); **(H)** Weedy River and Coastal Embankments, disturbed aquatic and coastal habitats (sea walls, docks, retaining walls, and natural features) (herbaceous perennials, prostrate, summer annuals, monocots, and deciduous vine); **(I)** Parking Lot Lagoon, impervious areas such as parking lots that collect precipitation and support ruderal plants (herbaceous perennials, prostrate, summer annuals, monocots). Photos by Christopher Kennedy.

urban vacant land. Researchers found many parcels are providing significant ES to residents with the majority of land (62%) covered with trees, herbaceous vegetation and grass, often in neighborhoods with similar rates of urban vegetative density, which suggest they are connected to and part of an "urban green matrix" and may be important to protect from development (See examples in **Figure 2**).

Although ruderal systems provide many benefits, they can also present tradeoffs or disservices. Some scientists point out, certain introduced plants or organisms can impact biodiversity, disrupt food webs, or influence ecosystem change (Potgieter et al., 2019). The presence of ruderal or novel ecosystems can also conjure notions of neglect and present procedural or logistical challenges for property owners and resource managers (Nassauer 1995; Li and Nassauer 2020). The economic impacts are key concerns as well, although some argue the costs are grossly inflated or misinterpreted, and likely due to inefficient or exploitative economic and trade practices (US Fish and Wildlife Service 2011; Pearce 2016). To date, researchers contend an increase in invasive species cannot be explained simply through competitive advantage but is a function of larger environmental change and adaptation (Davis 2003; MacDougall and Turkington 2005; Simberloff et al., 2012; Thomas 2013).

FIGURE 2 | Three ruderal landscapes in New York City. **(A)** A postindustrial forest on neglected land in Hunters Point South, Queens, New York, 2015; **(B)** A former auto repair shop in Crown Heights, Brooklyn, New York, 2017; **(C)** A ruderal site underneath the Van Wyck Expressway in Corona Flushing Meadows Park, Queens, New York, 2018. Photos by Christopher Kennedy.

CITIES AS PLACES FOR MULTISPECIES FLOURISHING

In order to conceptualize cities as spaces for "multispecies flourishing," a reconsideration of the idea of sustainability and sustainable development is needed (Connolly 2019). Researchers like Rupprecht et al. (2020) have recently proposed the concept of "multispecies sustainability," a revision of the Brundtland conception of sustainability which they point out does not sufficiently recognize interdependencies between humans and other species, and is thus ill-equipped to address future challenges long-term (UN Secretary-General 1987). This is grounded in the idea that well-being emerges from and depends upon a set of complex relations shaped by the agency and transformative potential of multispecies stakeholders (Manfredo et al., 2016). Through a process of translation that recognizes that different species have diverse traits, capacities, and functions, multispecies sustainability aims to address the shortcomings of human-focused and reductionist management systems (Haraway, 2016; Andersson and McPhearson 2018; Samuelsson et al., 2018). Rupprecht et al. (2020)'s framing is useful here particularly in how the authors articulate a trajectory for multispecies thinking that rejects "more-than-human well-being" as a normative premise or purely moralistic endeavor. Instead their conceptualization acknowledges that both scientific evidence and Indigenous knowledge bases support the idea that human prosperity and survival relies upon our interdependent relationship with other species. This articulation moves beyond the singular emphasis on shifting values and beliefs, and offers a more comprehensive ethical stance for multispecies thinking and approaches more broadly.

Over the past decade this ontological shift toward multispecies thinking has inspired several formulations within the humanities, social sciences, and critical geography such as multispecies ethnography (Kirksey 2014; Münster and Locke, 2015), more-than-human geographies (Lorimer 2012), transcorporeal subjectivity and posthumanism (Alaimo 2016), strategic anthropomorphism (Bennett 2010), intra-action (Barad 2007), and transspecies urban theory (Wolch 2002) which may benefit SES discourse. In large part these theories and ideas argue planning theory may benefit from an attunement to nonhuman perspective in order to ensure the idea of the "good city" is not reliant upon dualities and separations between human and nonhuman, culture and nature, or the overemphasis on mitigation of risks, which can ironically constrain the very institutions working to address emergent challenges (Seed and Macy 2007; Rupprecht et al., 2020). Scholars like Debra Solomon (2019) have since proposed the concept of multispecies urbanism which seeks to leverage design, adaptive planning, and governance to reorient the process of urbanization towards "strategies implemented by non-humans as a means to survive societies' crises of democracy, planetary climate catastrophe, and uneven resource distribution" (pg. 53). Multispecies urbanism acknowledges urban nature as a critical stakeholder, advocating for nature-based and ecological approaches to urban planning, governance, and resource management. It is important to distinguish this from a planning process or management strategy that uses ecological indicators of multiple species for instance. Multispecies planning is rather an integrated approach and philosophy that prioritizes urban natural worlds and ecologically driven policy and practice (Glaser et al., 2008; Setiadi, Nadhiroh, and Rupprecht 2021). The approach affirms cities as fundamentally ecological formations where city dwellers' lives are shaped not only by human infrastructure and capital, but also by the rich tapestry of more-than-human life, soils, water, and vegetation (Barua 2017; Barua and Sinha 2020). It also presents critical questions such as who has the right to a city and who has access to it, and issues of personhood status, even for organisms that are unwanted or nonhuman (Shingne 2020).

A number of these ideas build on a rich history of traditional practices, and Indigenous ways of knowing that recognize the animacy and agency of nonhuman actors in the environment, everything from plants and animals, to stones or elements of weather (Caston 2013; McMillen et al., 2020). In many cases, Indigenous communities have no conception of nature as separated from culture. This is described by Salmón (2000) as kincentric ecology, highlighting the reciprocal relationships between people and place, a form of community based intergenerational guardianship that is the responsibility of humans because of their privilege as "knowledge holders." In other traditions such as Hinduism or

Buddhism, the interconnection between humans and the natural world is emphasized through the dissolution of the self, which may be heightened through meditative practice and "non-dual spiritual experience." The writings and teachings of Buddhist monk Dōgen (1200–1253 BC), for instance, asserts all things have Buddha nature and describe the value of ongoing change and impermanence, which inform some Japanese and Chinese practices (Luchkova 2011; Droz 2020). Similarly, in traditional Hawaiian cultures the land is considered as a member of one's family, indicating an inherent responsibility for caretaking and stewardship.

More recent ecocentric views such as deep ecology (Naess 1988) advocate for the inherent value of all living beings despite human utility, while the field of ecofeminism frames the struggle for multispecies recognition and environmental justice within the context of a capitalist patriarchal society (Plumwood 1986). Of late, the notion of "naturecultures" (Haraway 2003) has also been used to recognize the inseparability of nature and culture, drawing from theories such as biocultural evolution and biocultural diversity (BCD) which argue cultural and biological diversity are interconnected (Elands et al., 2019). Further, biocultural stewardship models have since been proposed as a means to learn from the knowledge systems of Indigenous communities and other traditions to inform more effective approaches to land and resource management (Vierikko et al., 2016; McMillen et al., 2020). In contrast to Western scientific approaches, biocultural stewardship draws from multi-generational knowledge sources that seek a more relational model for planetary health, recognizing the value and kinship of all organisms within an ecosystem (Robinson et al., 2021). Recent research indicates that biocultural approaches may improve the viability and success of urban greening and restoration efforts, as well as well-being more generally (Kimmerer 2011; Uprety et al., 2012; Rozzi 2013; Reyes-García et al., 2019). In many parts of the world a biocultural perspective is already embraced, reflecting a history of spiritual and philosophical traditions that continue to influence planning theories which differ from a Western and European emphasis on non-human centered design. In New Zealand, the Maori culture embraces the idea that environments have living spirits and deserve protection and sovereignty, prompting the Parliament to grant legal standing to the Whanganui River and its tributaries. Ecuador (2008) and Bolivia (2010) adopted the rights of nature doctrines within their federal constitution, and in India the river Ganges was granted the legal status of personhood in 2017.

Ruderal landscapes may play an important role in further conceiving of biocultural approaches and the idea of a multispecies city. Ruderal plant and animal communities for instance often appear along the fringes and edges of urban areas, where biodiversity may flourish more so than the interior of the urban core because it is where multiple ecosystems intersect. McCay (2000) explains these ecological edges can have several benefits and bring together human and more-than-human communities. Practices such as urban agriculture and gardening is a salient example because it presents both an ecological and cultural edge where opportunities for genetic exchange between domesticated and wild plants can occur alongside the exchange of knowledge bases and cultural identities (Turner et al., 2003). Indigenous scholar Robin Wall Kimmerer (2015) in particular highlights the essential role of the ruderal, explaining the spontaneous plants that emerge in damaged landscapes are a form of "peacemaking" where a "community of weedy species can be a partner in restoration" (pg. 334).

Yet, as much as the multispecies city concept is alluring, we should tread cautiously and consider the associated risks. For instance, how we ethically leverage the ruderal and put multispecies planning perspectives into practice or try to speak on behalf of another organism is a key concern (Kirksey 2014). In attempting to translate another species' needs, there is an acute risk of becoming "ventriloquists" that represent other species through a human lens, pointing to a need to consider authentic processes of translation and how best to enter into an ethical agreement with another species. In many areas of the world, the chief concerns may be more related to social institutions or systemic injustices that require prioritization. Designing cities to meet the needs of multiple species while ignoring the needs of humans, equally presents a challenge to human health and wellbeing. Similarly, merely reducing cities to "safe havens" for other species also ignores the urgent need to imagine practices and languages for coexistence and mutual aid, and merely coopts the notion of multispecies thriving or urbanism. This ecocentric way of thinking may inadvertently dilute a responsibility or agency to forge reciprocal relations, and may ignore the different needs of other organisms.

MOVING TOWARD RUDERAL RESILIENCE

As researchers, planners and others recognize cities as complex, hybrid, and patchy, new articulations of resilience thinking are needed to both address historic and emerging issues of social equity and justice, and the impacts of climate and urbanization. To offer one potential approach, the concept of "ruderal resilience" is proposed, which may offer a useful device to not only think differently about emergent urban landscape forms but to also embrace a multispecies perspective in urban design, governance, and planning. The concept is not positioned as a new theory, but rather a potential perspective and way of thinking.

While there are many similarities and parallels to conventional resilience thinking or practice, **Table 1** summarizes some key differences. First, in a conventional view resilience is understood as the capacity of a system to absorb disturbance, to be adaptive, and to retain the same function or structure (Folke 2016). This approach is prevalent in many examples of urban planning or design which often focus on maintaining business-as-usual strategies like the use of gray infrastructure with the goal of mitigating damage, rather than adapting to new conditions, or consideration of the needs and affordances of other species (Depietri and McPhearson 2017). If we apply a ruderal lens, the disturbance-tolerating life strategy that enables ruderal plants to recover rapidly to challenging environmental conditions offers a new way of thinking about temporality, change, and disturbance. In a ruderal approach disturbance is framed as something to leverage and anticipate, with the goal of generating novel metastable conditions in response to new mixes of species or social-ecological conditions (Higgs 2017). Disturbance in this sense is viewed as an opportunity and inevitability that urban systems or plant communities can take advantage of, and rapidly adapt to, rather than mitigate or avoid.

Ruderal ecological systems are also highly adaptive, and demonstrate an ability to hybridize and evolve in a relatively short time period and across multiple scales, geographies, and SES (Donihue and Lambert 2015). While conventional applications of resilience thinking may seek similar goals, the temporality and approach can differ. In many cases the time scale for implementing an urban resilience strategy is determined by particular forms of decision making, political arrangements, or procedural issues that may not allow for flexibility or timely implementation, and may not include a diversity of voices. What's more, the livelihood of human communities is prioritized, often to the detriment of ecosystem health or mutual flourishing. Ruderal systems in contrast are often more flexible and responsive, embracing ecological time scales that allow for both rapid and short-term adaptations, as well as longer term processes such as building and remediating soils (e.g., phytoremediation). Ruderal systems are also more biodiverse than some urban areas such as parks or manicured green spaces, and can support mutualistic synergies between animals, insects and human communities, rather than just one or the other.

Third, ruderal ecological systems are inherently transformative, characterized by their ability to cross an ecological threshold and to form self-sustaining ecological systems. In most conventional understandings of resilience, transformation is rarely linked to notions of self-organization, and has more to do with interventions into particular forms of resource management or governance. Transformation in this sense will often happen at a relatively slow pace, and the governance mechanisms employed often raise issues of authentic representation and procedural justice. A ruderal perspective acknowledges the critical need to support the agency, self-organization, and self-determination of communities to ensure inclusive planning and decision-making. Finally, in relation to stewardship and co-management, much of resilience thinking is focused on stewardship in the service of human interests or aspects of urban nature valued by people, often with a specific aesthetic and use-value approach. Because ruderal systems are self-assembling, they in contrast require little or no management, and can provide multiple benefits to both humans and nonhumans simultaneously. More than this, many ruderal systems can be regenerative or increase benefits rather than merely sustaining functions, particularly when located on damaged land disturbed by human activities. Considering these differences, ruderal resilience is the capacity of social-ecological systems to leverage and rapidly adapt to disturbances, to self-organize or self-assemble, and to regenerate previous functions of the system while also providing new benefits for multiple stakeholders (human and other species).

Yet, importantly, ruderal resilience entails a critical examination of the edges and overlooked areas of cultural, ecological, social, and political domains as sites of contestation, reparation and justice. Resilience in this sense is not just a measure of a system's capacity to absorb disturbance and sustain functions to meet human needs, but rather the capacity of social-ecological systems to interrogate historic and ongoing disturbances (social, ecological, technological, and political challenges) and ability to transform (or regenerate) in ways that seek mutualistic synergies and interdependencies of human and more-than-human life. Stoetzer (2018) explains how this ruderal perspective can potentially interrupt nature-culture divides, allowing for new understandings of how global and hyper-local conditions influence changes in urban forms, the migration of peoples and other species, and how injustices and oppressions influence biophysical and ecological processes.

For example, the notion of hybridity, increasingly exhibited by ruderal plants, may indicate a need to think differently about diverse collaborations and multi-stakeholder representation as well as transdisciplinary decision-making. Similarly, a consideration of dynamic temporality may aid in our understanding of the mismatches between human and ecological time scales, and the ability for governance and policy to be flexible and nimble. The function of bioremediation, which similarly is observed in some ruderal plant communities, offers an opportunity to reconsider notions of regeneration, repair, and reconciliation that must occur both socially, spatially, and ecologically to ensure equitable urban greening strategies. And the concept of communicative mutualisms, or the symbiotic relationships and communication between multiple organisms, surface ideas of decentralized and networked strategies that can be applied to a range of contexts or social movements (Richardson et al., 2000).

Ruderal resilience is not a call for rewilding of cities, nor the abandonment of all management strategies, but rather a critical attunement to the interdependencies of more-than-human and human communities. Although this may not be applicable to all contexts, this formulation may help to advance more equitable forms of urban governance by expanding the scope of actors considered as part of SES, while also providing examples of novel strategies that rethink the status quo such as commonly used approaches to resource management, urban greening, and development. Integral to engaging in these strategies is an iterative process of co-constructing a vision for multispecies flourishing, a process that should also seriously address issues of equity, indigenous representation, systemic racism, among other vital issues.

Shifting Worldviews Through Multispecies Ruderal Entanglements

To embrace a ruderal and multispecies ethic, particularly in the Global North, may require a confrontation both physically and conceptually with human-centered thinking and a reframing of the objectives of planning theory and practice (Plumwood 2009;

Houston et al., 2018). This should involve a critical consideration of non-Western and Indigenous practices, ideologies, and traditions, which often showcase alternative conceptions of planning or stewardship. Direct engagements, encounters, and embodied experiences with ruderal landscapes could offer an approach to initiate a shift toward a multispecies ethic, especially within cultural contexts where nature-culture divides persist. Houston et al. (2018) describes this as "multispecies entanglement," a process of attunement involving interactions with urban nature that integrates Indigenous knowledge or new ways of knowing. This is not the practice of simply walking through a park, but rather a process of "becoming-with," appreciating shared worlds along the margins, and the critical task of imagining new forms of expressing interdependency.

Why the ruderal edges? Some researchers point out that encouraging interactions with the margins of urban spaces, and the organisms we label as invasive, alien or feral, may aid in city dwellers' understanding of how we share worlds with a diverse set of lifeforms, more so than merely experiencing nature we have conceptualized as pristine or untouched (Hustak and Myers 2012; Pellegrini and Baudry 2014; Vega and Schläpfer-Miller 2021). The process of entanglement can be initiated with the simple gesture of observing and engaging with a ruderal edge. Taking time to look carefully at life in a sidewalk crack or vacant lot for instance, may help facilitate an examination of our collective impact on the earth while also building empathy for more-than-human worlds (Pellegrini and Bauldry 2014; Vega and Schläpfer-Miller 2021). Through forms of attunement, deep listening, and embodied experience the vacant lot behind your house may cease to be conceptualized as a mere void, or the plants and animals residing there as "alien" and "other," but rather a different kind of lifeway that is interwoven with our health and livelihoods.

The artist group the Environmental Performance Agency (EPA) for instance uses movement scores among other strategies to structure ruderal encounters in New York City, encouraging new states of awareness through exercises that help participants as Michael Marder (2012) would say, "let go of our fixed association of [the] biological... based on our human selves and limitations" (p. 124). EPA agent andrea haenggi describes this as a form of "ruderal actionism" referencing the Viennese Actionism movement that catalyzed performance art in the 1960's (Hoyer and Almeida 2021). While the encounter is a critical access point, communication is key as well, unfolding through forms of embodiment. This is often a nonverbal, physical "being-with" or what Anna Tsing describes as a means to enter into the social worlds of other organisms (Tsing and Elkin 2018).

Yet, it is important to consider that for some this may not be an easy task, or always an effective approach. For many, the presence of USV can conjure notions of neglect and present procedural or logistical challenges for property owners and resource managers (Khew et al., 2014; Li and Nassauer 2020). Joan Iverson Nassauer's (1995) research on landscape perception and environmental function, which was developed into the "Cues to Care" framework, finds that many people prefer landscapes they recognize as designed or signal ongoing human care for the landscape rather than the more messy but beneficial functions of semi-wild or unmaintained areas. Nassauer advocates instead for forging synergies between cultural, aesthetic and ecological goals in caring for and designing landscapes to ensure cultural ecological services can effectively circulate. In these circumstances, another strategy may be necessary to cultivate empathy for landscapes and organisms deemed as pests, nuisance, or perceived as unattractive.

Cultivating Cultures of Reciprocity and Care Through Biocultural Stewardship

While direct engagements with ruderal landscapes may help to shift perspectives, there is also a need to develop this into a practice of care and long-term stewardship. This may require new biocultural tactics and a further reframing of conventional restoration, conservation, or stewardship approaches. The practice of care or maintenance has many histories entwined with human and more-than-human cultures, but is often influenced by dominant political, social, cultural and technological ideologies. In the Global North, the move toward individualism and a reductionist siloing of disciplines influenced the prioritization of self-care rather than the notion of community care or mutual aid, a mindset that can differ radically in other cultures (Bellacasa 2017). In the context of conservation and land management, civic environmental stewardship, or the range of activities that individuals or community groups use to care for their neighborhoods or place, is similarly beholden to shifting interpretations of what care means, for whom, and how (Svendsen and Campbell, 2008; Connolly et al., 2013). Although the practice of stewardship typically connotes a responsibility to protect and care for the natural environment, stewardship efforts are often organized around the idea of conserving resources for human use, and may not always be inclusive of cultural practices or traditions, limiting the scope of actor networks involved (Bennet et al., 2018). Low income and POC communities for instance have historically been excluded from conservation movements in part because nature we deem as valuable (e.g., maintained pastoral landscapes), are typically located in white and wealthy communities (Bullard 1999). Even the notion of ecosystem services connotes, at least semiotically, that natural systems provide nonhuman labor that humans can utilize, rather than the idea of mutual aid or that human and more-than-human communities care for and provide benefits to each other simultaneously.

Bellacasa (2017) in her analysis of the ethics of care urges us to consider the practice of permaculture as an alternative framing. Permaculture ethics stress the interconnectivity and maintenance of multiple natural and human-cultural systems ("cultural landscapes") to generate abundance for self and the earth simultaneously. Permaculture also encourages us to notice the edges of a system, and to challenge the assumption that we are merely a caretaker or masters of a place, but also direct participants that co-create naturecultures. Indigenous scholar Robin Wall Kimmerer's (2011) work on "reciprocal restoration," the notion that restoration of land and culture are mutually constitutive, is key in considering this. Kimmerer draws from a rich history of traditional ecological knowledge to explain that landscapes are not necessarily "broken" but rather our relationship with land more broadly is fractured. She advocates here for cultivating renewed relations to allow for mutual flourishing, what Salmón (2000) describes as "kincentrically managing the land." The act of stewardship or restoration in this sense is not a return to a romanticized vision of a native landscape, but rather an opportunity for reciprocal caregiving and shared accountability of hybridized landscapes in-the-making (Geist and Galatowitsch 1999). This is fundamentally a biocultural practice of stewardship that integrates diverse knowledge systems with place-based practices that are particularly needed to address emergent urban social-ecological challenges (McMillen et al., 2020).

Ruderal landscapes offer a unique space to experiment with this in practice. The ruderal is often an indicator of disturbance and human impact, highlighting areas that require acute care and attention. In some cases they may also surface contested histories and thus offer a bridge to consider social problems as inseparable from ecological or political ones. For resource managers, caring for the ruderal may offer an opportunity to better understand the needs of multiple species, which then inform management strategies, alongside ongoing consultation with local groups and Indigenous communities. For stewardship or conservation groups, the development of ruderal "carescapes," sites where communities can begin to develop a relationship with damaged terrains, may help reframe conventional notions of care and restoration toward regenerative models of self-healing and mutualism, and raise important questions about the ethical obligation to care for more-than-human worlds. At the same time this reframing allows for new governance approaches to emerge that can be inclusive of more-than-human needs and functions, many of which have been discussed or since practiced such as mosaic governance (Buijs et al., 2019) or biocultural design (Davidson-Hunt et al., 2012).

This may first involve collaborative investigations of social-ecological interactions across various urban forms and scales, looking particularly at the ruderal edges for new insights, biocultural approaches, relationships, and patterns. In some cases the adaptive capacities, services or disservices of a ruderal ecology may offer crucial insights to ascertain the emergent needs of human communities and other species. These biocultural indicators can then be used to define the context of a particular urban challenge, the scope of the assessment, and performance goals that aim towards multispecies flourishing and regeneration rather than merely mitigating damage, or planning for human adaptation. This may not be an easy task, but rather a long-term process of unlearning, decolonizing, and honoring a relationship with the diverse urban lifeways that we often ignore. Here we can begin to meet plants, ecosystems and people where they are rather than where we want them to be, and to view urban environments as networks of mutual aid that require ongoing reciprocity.

Multispecies Urbanism, Planning and Governance

Central to realizing multispecies approaches to urbanism, planning or governance is understanding urban terrains as assemblages of human and more-than-human actors that influence the circulation and trajectory of political networks (McFarlane 2009; Celermajer et al., 2020). A multispecies approach thus recognizes these connections and centers the knowledge of more-than-human stakeholders to move beyond a logic of control, security or safety toward one of mutual appreciation and reciprocity (Steele et al., 2019). This may require the consideration of different temporal scales as well as novel strategies for attunement and co-envisioning futures. Manring's (2007) notion of adaptive governance is useful, which they frame as a process of social learning and trust to inform decision making processes across various domains and takes into consideration the role of "scale-crossing brokers" in thinking about ecological scales and the needs of multiple species (Ernston et al., 2010). Ruderal landscapes again present a salient touchstone, a means to observe how nonhuman and human actors interact through forms of self-organization, the adaptations needed to thrive, and the associated (dis)services. These indicators may aid planners in developing strategies and solutions that embrace uncertainty and change, notions of self-assembly, and synergies between social, cultural, economic and technological systems.

For city planners this may entail a revision of conventional tools such as environmental impact assessments (EIA) or cost-benefit analyses (CBA), which focus on the monetary valuation of natural resources. Although useful, these tools rarely include a consideration of the regulating services or the intangible and social values people place on urban greenspaces and cultural systems (Langemeyer et al., 2016). Instead, urban ecologists advocate for using a multi-criteria decision analysis (MCDA) which clearly defines and weights criteria to help prioritize land use planning and manage conflicting perspectives (Langemeyer et al., 2016). Yet to date, most MCDA models ignore nonhuman perspectives or integrated knowledge systems (e.g., Traditional Ecological Knowledge, ethnobotany) to understand ecological resilience, adaptive capacity, and what factors drive social and ecological interactions within a system. Sterling et al. (2017) propose the use of biocultural indicators as a way to integrate ecological, social and cultural factors, which in turn may be used to understand social-ecological change or shifts in cultural diversity. For instance, how phenomena such as a decline in biodiversity or an increase in extreme weather events may be an indicator of extractive economic systems, social inequity, or large-scale human migration (Schell et al., 2020). Biocultural indicators are then a more robust way to understand feedback between ecological and cultural systems, which can then be used to co-develop locally-appropriate benchmarks and methods to inform resource management, policy, and development.

As an example, David Morgan's (2019) analysis of the Mass Oyster Reef project considers the possibility of multispecies planning and what he calls "post-Natural policy." Morgan (2019a) interrogates the shortcomings of the Massachusetts Shellfish Planting Guidelines issued by the Division of Marine Fisheries, which develops maps and surveys levels of contamination to determine suitable areas for fishing or shellfish planting. In talking with restorationists, Morgan found the Marine Fisheries maps were so heavily oriented towards human ends that they inadvertently limited the cultivation of "self-perpetuating shellfish populations" in areas that restorationists argue would be suitable. Morgan instead developed an "Oysterscapes" map using species-specific criteria for the Eastern oyster, showing that many areas were favorable for oyster reef restoration and could be implemented without damaging existing fishing infrastructure. In many ways, this is perhaps an example of ruderal resilience in action.

Other examples are emerging (Campos-Silva et al., 2018). Rupprecht et al. (2020) highlight an initiative in Auckland, New Zealand that brought together bees, beekeepers and city officials (For the Love of Bees) to consider multispecies urban greening strategies (Hyvärinen 2019), and also the Healthy Urban Microbiome Initiative, which aims to showcase the co-benefits of microbial biodiversity and human health. Thomsen et al. (2021) consider how wildlife tourism can be reframed using a multispecies livelihoods framework to eliminate "animal-human" divides and embrace more ethical practices. Or the Texas Department of Transportation's Bats'n'Bridges program which encourages the design of bridges and culverts that allow local bat communities to roost and provide ecological and cultural services to urban areas. The aim here is not to merely design for other species, but rather to consider how planning can be mutually beneficial for multiple species over a long duration. New policy formations like personhood status for ecosystems, while well-intended, may simply reinscribe a human-centered perspective to nonhumans, rather than recognizing their sovereign agency and the value of including them in legitimate decision-making processes.

CONCLUSION

By 2030, the United Nations predicts that 68% of the world's population will live in cities, but likely half of the urban areas that will exist by 2050 have yet to be designed or created (United Nations Department of Economic and Social Affairs 2018; Childers 2019; Moraci et al., 2020). This presents a unique opportunity to rethink how cities can work with the increasingly hybrid and anthropogenic landscapes left behind. At the same time the acceleration of the climate crisis makes it imperative that we seek new approaches and ways of knowing that promote forms of urban resilience which are equitable, flexible, and impactful. In many ways, ruderal ecological systems are already demonstrating a path forward, showcasing an ability to thrive precisely because of the multispecies entanglements taking place along the edges of many urban centers around the world.

An ongoing examination of ruderal systems, their adaptive capacities, ecological functions and social-ecological relationships, may offer a useful device to envision and realize these approaches, while also advancing resilience thinking and SES theory toward an integrated framework of biocultural stewardship, multispecies planning, and governance. This is not a means for advocating for certain plants or ecosystems as having superior advantage, but rather a ruderal lens provides an opportunity to consider life along the margins which may help guide an epistemological shift in how we value, care for, and perceive multispecies life in cities. The ruderal for instance showcase that borders are not always barriers but also opportunities for multispecies lifeways; hybridity can enhance diversity and survival; there is strength in moving horizontally and not just vertically; dynamic adaptation and inclusive decision-making is key; systems need to be considered at multiple scales both temporally and spatially; and there is power in mutualistic communication.

Yet, there also are several limitations to consider. First, the ruderal or multispecies approach is not a catch-all solution for urgent social-ecological challenges facing communities across the world. Rather, to address the climate crisis and other issues will require multiple approaches and methods, and stakeholders and communities should remain critical of how multispecies thinking and planning is translated, adopted, or utilized. Due to the recent emergence of multispecies studies, there is limited prior research on the effectivity or application of multispecies thinking to urban planning and design. Additionally, the scope of perspectives included in this review emphasize research and approaches within the context of the Global North, and thus may not be applicable to some areas or contexts. Further consideration should be taken to ensure a diversity of non-western and Indigenous perspectives are centered.

Finally, to authentically embrace and work with the notion of ruderal resilience, planners, researchers and others must be open to others ways of knowing that are critical of reductionist approaches to planning and conservation, as well as the diverse multispecies lifeways that many avoid. In this mutual dialogue we may begin to attend to more-than-human needs, enabling us to build even greater resiliency because we are developing a literacy to aid in our preparation for further change and adaptation, rather than assume a return to "balance" through human-centered practices. Here in the discomfortability of the ruderal, we may gain a new appreciation for our interdependence with all lifeforms, and perhaps motivate a new kind of social-ecological resilience moving forward.

AUTHOR CONTRIBUTIONS

This article features work from contributing author, CK, with advisement from Dr. Timon McPhearson and Dr. Zbigniew Grabowski, Urban Systems Lab, The New School.

ACKNOWLEDGMENTS

I would like to thank Dr. Timon McPhearson and Dr. Zbigniew Grabowski for their input on the article.

REFERENCES

Adams, L. W. (1994). *Urban Wildlife Habitats: A Landscape Perspective*. Minneapolis, Minnesota, USA: University of Minnesota Press.

Ahern, J. (2016). Novel Urban Ecosystems: Concepts, Definitions and a Strategy to Support Urban Sustainability and Resilience. *Landscape Architecture Front.* 4. Available at: https://scholarworks.umass.edu/larp_faculty_pubs/66.

Alaimo, S. (2016). *Exposed: Environmental Politics and Pleasures in Posthuman Times*. Minneapolis, Minnesota, USA: University of Minnesota Press.

Alexander, C., Neis, H., Anninou, A., and King, I. (1987). *A New Theory of Urban Design*. Oxford: Oxford University Press.

Anderies, J. M. (2014). Embedding Built Environments in Social-Ecological Systems: Resilience-Based Design Principles. *Building Res. Inf.* 42, 130–142. doi:10.1080/09613218.2013.857455

Anderson, E. C., and Minor, E. S. (2020). Management Effects on Plant Community and Functional Assemblages in Chicago's Vacant Lots. *Appl. Veg Sci.* 23, 266–276. doi:10.1111/avsc.12480

Anderson, E. C., and Minor, E. S. (2017). Vacant Lots: An Underexplored Resource for Ecological and Social Benefits in Cities. *Urban For. Urban Green.* 21, 146–152. doi:10.1016/j.ufug.2016.11.015

Anderson, K. M. (2009). Marginal Nature: Urban Wastelands and the Geography of Nature. Available at. Available at: https://repositories.lib.utexas.edu/handle/2152/ETD-UT-2009-12-604 (Accessed March 8, 2021).

Andersson, E., Haase, D., Anderson, P., Cortinovis, C., Goodness, J., Kendal, D., et al. (2021). What Are the Traits of a Social-Ecological System: towards a Framework in Support of Urban Sustainability. *Npj Urban Sustain.* 1, 1–8. doi:10.1038/s42949-020-00008-4

Andersson, E., and McPhearson, T. (2018). Making Sense of Biodiversity: The Affordances of Systems Ecology. *Front. Psychol.* 9, 594. doi:10.3389/fpsyg.2018.00594

Anderson, P., and Elmqvist, T. (2012). Urban Ecological and Social-Ecological Research in the City of Cape Town: Insights Emerging from an Urban Ecology CityLab *Ecol. Soc.* 17 (4).

Angelidou, M. (2015). Smart Cities: A Conjuncture of Four Forces. *Cities* 47, 95–106. doi:10.1016/j.cities.2015.05.004

Armitage, D. (2007). Governance and the Commons in a Multi-Level World. *Int. J. Commons* 2, 7–32. doi:10.18352/ijc.28

Aronson, M. F. J., La Sorte, F. A., Katti, M., Goddard, M. A., Lepczyk, C. A., Warren, P. S., et al. (2014). A Global Analysis of the Impacts of Urbanization on Bird and Plant Diversity Reveals Key Anthropogenic Drivers. *Proc. R. Soc. B.* 281, 20133330. doi:10.1098/rspb.2013.3330

Bäckstrand, K. (2006). Multi-stakeholder Partnerships for Sustainable Development: Rethinking Legitimacy, Accountability and Effectiveness. *Eur. Env.* 16, 290–306. doi:10.1002/eet.425

Bahrainy, H., and Bakhtiar, A. (2016). *Toward an Integrative Theory of Urban Design*. Berlin, Germany: Springer.

Ban, N. C., Mills, M., Tam, J., Hicks, C. C., Klain, S., Stoeckl, N., et al. (2013). A Social-Ecological Approach to Conservation Planning: Embedding Social Considerations. *Front. Ecol. Environ.* 11, 194–202. doi:10.1890/110205

Banz, G. (1970). *Elements of Urban Form*. First Edition. New York: McGaw - Hill Book Company, Inc.

Barad, K. (2007). *Meeting the Universe halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham, NC, USA: Duke University Press Books.

Barrett, N. F. (2011). The Promise and Peril of Ecological Restoration: Why Ritual Can Make a Difference. *Am. J. Theology Philos.* 32, 139–155.

Barthel, S., Colding, J., Ernstson, H., Erixon, H., Grahn, S., Kärsten, C., et al. (2013). *Principles of Social-Ecological Urbanism - Case Study: Albano Campus, Stockholm*. Stockholm, Sweden: Stockholm Resilience Centre.

Barua, M., and Sinha, A. (2020). "Cultivated, Feral, Wild: The Urban as an Ecological Formation," in ERC Horizon 2020 Urban Ecologies Research Project, 1–17.

Barua, M. (2017). Nonhuman Labour, Encounter Value, Spectacular Accumulation: the Geographies of a Lively Commodity. *Trans. Inst. Br. Geogr.* 42, 274–288. doi:10.1111/tran.12170

Beder, S. (1998). *Global Spin: The Corporate Assault on Environmentalism*. Hartford, Vermont, USA: Chelsea Green Publishing Company.

Beerling, D. (1991). The Testing of Cellular concrete Revetment Blocks Resistant to Growths of Reynoutria Japonica Houtt (Japanese Knotweed). *Water Res.* 25, 495–498. doi:10.1016/0043-1354(91)90088-8

Bellacasade la, M. P. (2017). *Matters of Care: Speculative Ethics in More than Human Worlds*. 3rd ed. Minneapolis, Minnesota, USA: University of Minnesota Press.

Bennett, J. (2010). *Vibrant Matter: A Political Ecology of Things*. Durham, NC, USA: Duke University Press Books.

Bennett, N. J., Whitty, T. S., Finkbeiner, E., Pittman, J., Bassett, H., Gelcich, S., et al. (2018). Environmental Stewardship: A Conceptual Review and Analytical Framework *Environ. Manage.* 61 (4), 597–614. doi:10.1007/s00267-017-0993-2

Berkes, F., Colding, J., and Folke, C. (2003). *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. 1st edition. Cambridge, UK: Cambridge University Press.

Berkes, F. (2009). Evolution of Co-management: Role of Knowledge Generation, Bridging Organizations and Social Learning. *J. Environ. Manage.* 90 (5), 1692–1702. doi:10.1016/j.jenvman.2008.12.001

Berkes, F., Folke, C., and Colding, J. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge, UK: Cambridge University Press.

Betz, N., and Coley, J. (2021). Human Exceptionalism: A Cognitive Barrier to Understanding and Engaging with Global Climate Change. *OSF Preprints*. doi:10.31219/osf.io/36ymb

Bonthoux, S., Voisin, L., Bouché-Pillon, S., and Chollet, S. (2019). More Than Weeds: Spontaneous Vegetation in Streets as a Neglected Element of Urban Biodiversity. *Landscape Urban Plann.* 185, 163–172. doi:10.1016/j.landurbplan.2019.02.009

Bowman, A. O. M., and Pagano, M. A. (2000). Transforming America's Cities. *Urban Aff. Rev.* 35, 559–581. doi:10.1177/10780870022184534

Brand, P. (2007). Green Subjection: The Politics of Neoliberal Urban Environmental Management. *Int. J. Urban Reg. Res* 31, 616–632. doi:10.1111/j.1468-2427.2007.00748.x

Buijs, A., Hansen, R., Van der Jagt, S., Ambrose-Oji, B., Elands, B., Lorance Rall, E., et al. (2019). Mosaic Governance for Urban green Infrastructure: Upscaling Active Citizenship from a Local Government Perspective. *Urban For. Urban Green.* 40, 53–62. doi:10.1016/j.ufug.2018.06.011

Bullard, R. D. (1999). in *Confronting Environmental Racism: Voices from the Grassroots*. Editor R. D. Bullard. 1st edition (Boston, MA, USA: South End Press).

Campos-Silva, J. V., Hawes, J. E., Andrade, P. C. M., and Peres, C. A. (2018). Unintended Multispecies Co-benefits of an Amazonian Community-Based Conservation Programme. *Nat. Sustain.* 1, 650–656. doi:10.1038/s41893-018-0170-5

Carne, R. (1994). "Urban Vegetation: Ecological and Social Value," in National Greening Australia Conference, Fremantle, Western Australia.

Caro, R. A. (1974). *The Power Broker: Robert Moses and the Fall of New York*. New York: Vintage Books.

Caston, D. (2013). Biocultural Stewardship: A Framework for Engaging Indigenous Cultures. *Cent. Humans Nat.* Available at: https://www.humansandnature.org/biocultural-stewardship-a-framework-for-engaging-indigenous-cultures.

Celermajer, D., Schlosberg, D., Rickards, L., Stewart-Harawira, M., Thaler, M., Tschakert, P., et al. (2020). Multispecies justice: Theories, Challenges, and Multispecies justice: Theories, Challenges, and a Research Agenda for Environmental Politics. *Environ. Polit.* 30, 119–140. doi:10.1080/09644016.2020.1827608

Chai, Y., Yue, M., Wang, M., Xu, J., Liu, X., Zhang, R., et al. (2016). Plant Functional Traits Suggest a Change in Novel Ecological Strategies for Dominant Species in the Stages of forest Succession. *Oecologia* 180, 771–783. doi:10.1007/s00442-015-3483-3

Chapin, Iii, F. S., and Starfield, A. M. (1997). Time Lags and Novel Ecosystems in Response to Transient Climatic Change in Arctic Alaska. *Climatic Change* 35, 449–461. doi:10.1023/a:1005337705025

Chen, X., Wang, W., Liang, H., Liu, X., and Da, L. (2014). Dynamics of Ruderal Species Diversity under the Rapid Urbanization over the Past Half century in Harbin, Northeast China. *Urban Ecosyst.* 17, 455–472. doi:10.1007/s11252-013-0338-8

Chester, M. V., Markolf, S., and Allenby, B. (2019). Infrastructure and the Environment in the Anthropocene. *J. Ind. Ecol.* 23, 1006–1015. doi:10.1111/jiec.12848

Chew, M. K., and Hamilton, A. L. (2010). The Rise and Fall of Biotic Nativeness: A Historical Perspective, 35, 47. doi:10.1002/9781444329988.ch4

Childers, D., Cadenasso, M., Grove, J., Marshall, V., McGrath, B., and Pickett, S. (2015). An Ecology for Cities: A Transformational Nexus of Design and Ecology to advance Climate Change Resilience and Urban Sustainability. *Sustainability* 7, 3774–3791. doi:10.3390/su7043774

Childers, D. L., Bois, P., Hartnett, H. E., McPhearson, T., Metson, G. S., and Sanchez, C. A. (2019). Urban Ecological Infrastructure: An Inclusive Concept for the Non-built Urban Environment. *Elementa: Sci. Anthropocene* 7, 385. doi:10.1525/elementa.385

Chu, E. K., and Cannon, C. E. (2021). Equity, Inclusion, and justice as Criteria for Decision-Making on Climate Adaptation in Cities. *Curr. Opin. Environ. Sustainability* 51, 85–94. doi:10.1016/j.cosust.2021.02.009

Clément, G. (2016). *Manifeste du Tiers paysage*. Rennes, France: Editions du commun.

Colding, J., and Barthel, S. (2019). Exploring the Social-Ecological Systems Discourse 20 Years Later. *Ecol. Soc.* 24 (1), 2. doi:10.5751/ES-10598-240102

Cole, R. J., Oliver, A., and Robinson, J. (2013). Regenerative Design, Socio-Ecological Systems and Co-evolution. *Building Res. Inf.* 41, 237–247. doi:10.1080/09613218.2013.747130

Conesa, H. M., and Faz, Á. (2011). Metal Uptake by Spontaneous Vegetation in Acidic Mine Tailings from a Semiarid Area in South Spain: Implications for Revegetation and Land Management. *Water Air Soil Pollut.* 215, 221–227. doi:10.1007/s11270-010-0471-4

Connolly, C. (2019). From Resilience to Multi-Species Flourishing: (Re)imagining Urban-Environmental Governance in Penang, Malaysia. *Urban Stud.* 57, 1485–1501. doi:10.1177/0042098018807573

Connolly, J. J., Svendsen, E. S., Fisher, D. R., and Campbell, L. K. (2013). Organizing Urban Ecosystem Services through Environmental Stewardship Governance in New York City. *Landscape Urban Plann.* 109, 76–84. doi:10.1016/j.landurbplan.2012.07.001

Convention on Biological Diversity, Subsidiary Body on Scientific, and Technical and Technological Advice (2000). Recommendation V/10 Ecosystem Approach: Further Conceptual Elaboration. Recommendations Adopted by the SBSTTA Fifth Meeting, 31 January–4 February 2000, Montreal. Available at: https://www.cbd.int/doc/recommendations/sbstta-05/full/sbstta-05-rec-en.pdf.

Cordeau, S., Ryan, M. R., Bohan, D. A., Reboud, X., and Chauvel, B. (2017). Which Traits Allow weed Species to Persist in Grass Margin Strips? *Weed Sci.* 65, 381–394. doi:10.1017/wsc.2016.39

Crawley, M. J. (2004). Timing of Disturbance and Coexistence in a Species-Rich Ruderal Plant Community. *Ecology* 85, 3277–3288. doi:10.1890/03-0804

D'Antonio, C., and Meyerson, L. A. (2002). Exotic Plant Species as Problems and Solutions in Ecological Restoration: A Synthesis. *Restor Ecol.* 10, 703–713. doi:10.1046/j.1526-100X.2002.01051.x

Da Cunha, A., Mager, C., Matthey, L., Pini, G., Rozenblat, C., and Véron, R. (2012). Urban Geography in the Era of Globalization: the Cities of the Future Emerging Knowledge and Urban Regulations. *Geogr. Helv.* 67, 67–76. doi:10.5194/gh-67-67-2012

Daniels, T. L. (2009). A Trail across Time: American Environmental Planning from City Beautiful to Sustainability. *J. Am. Plann. Assoc.* 75, 178–192. doi:10.1080/01944360902748206

Davidson-Hunt, I., Turner, K., Mead, A., Cabrera-Lopez, J., Bolton, R., Idrobo, C., et al. (2012). Biocultural Design: A New Conceptual Framework for Sustainable Development in Rural Indigenous and Local Communities. *S.A.P.I.EN.S* 5, 33–45.

Davies, O., and Riach, K. (2019). From Manstream Measuring to Multispecies Sustainability? A Gendered reading of Bee-ing Sustainable. *Gend. Work Organ.* 26, 246–266. doi:10.1111/gwao.12245

Davis, M. A. (2006). "Conceptual Ecology and Invasion Biology: Reciprocal Approaches to Nature," in *Conceptual Ecology and Invasion Biology: Reciprocal Approaches to Nature*. Editors M. W. Cadotte, S. M. Mcmahon, and T. Fukami (Dordrecht: Springer Netherlands), 35–64. doi:10.1007/1-4020-4925-0

Davis, M. A. (2009). *Invasion Biology*. Oxford: Oxford University Press.

Davis, M. (2012). Harm Is in the Eye of the Beholder. *Earth Isl. J.* Available at: https://www.earthisland.org/journal/index.php/magazine/entry/davis/ (Accessed November 2, 2020).]

Davis, M. A., Anderson, M. D., Bock-Brownstein, L., Staudenmaier, A., Suliteanu, M., Wareham, A., et al. (2015). Little Evidence of Native and Non-native Species Influencing One Another's Abundance and Distribution in the Herb Layer of an Oak woodland. *J. Veg Sci.* 26, 1005–1012. doi:10.1111/jvs.12302

Davis, M. A. (2003). Biotic Globalization: Does Competition from Introduced Species Threaten Biodiversity? *BioScience* 53, 481–489. doi:10.1641/0006-3568(2003)053[0481:bgdcfi]2.0.co;2

Davis, M. A., Chew, M. K., Hobbs, R. J., Lugo, A. E., Ewel, J. J., Vermeij, G. J., et al. (2011). Don't Judge Species on Their Origins. *Nature* 474, 153–154. doi:10.1038/474153a

Depietri, Y., and McPhearson, T. (2017). "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," in *Nature-based Solutions to Climate Change Adaptation in Urban Areas*. Editors N. Kabisch, H. Korn, J. Stadler, and A. Bonn (Berlin, Germany: Springer), 91–109. doi:10.1007/978-3-319-56091-5_6

Didham, R. K., Tylianakis, J. M., Hutchison, M. A., Ewers, R. M., and Gemmell, N. J. (2005). Are Invasive Species the Drivers of Ecological Change? *Trends Ecol. Evol.* 20, 470–474. doi:10.1016/j.tree.2005.07.006

Donihue, C. M., and Lambert, M. R. (2015). Adaptive Evolution in Urban Ecosystems. *Ambio* 44, 194–203. doi:10.1007/s13280-014-0547-2

Douglass, M. (2015). "Planetary Urbanization without Cities Bringing in the Local State and the Public City for Human and Planetary Flourishing," in Conference: Rethinking Asian Studies: The Idea of the City in Asian Contexts and City Theory for the New Millennium, Shanghai, China.

Droz, L. (2020). Living through Nature: Capturing Interdependence and Impermanence in the Life Framework of Values. *Philos. Life* 10 (1), 78–97.

Elands, B. H. M., Vierikko, K., Andersson, E., Fischer, L. K., Gonçalves, P., Haase, D., et al. (2019). Biocultural Diversity: A Novel Concept to Assess Human-Nature Interrelations, Nature Conservation and Stewardship in Cities. *Urban For. Urban Green.* 40, 29–34. doi:10.1016/j.ufug.2018.04.006

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., et al. (2019). Sustainability and Resilience for Transformation in the Urban century. *Nat. Sustain.* 2 (4), 267–273. doi:10.1038/s41893-019-0250-1

Elmqvist, T., Andersson, E., McPhearson, T., Bai, X., Bettencourt, L., Brondízio, E., et al. (2021). Urbanization in and for the Anthropocene. *Npj Urban Sustain.* 1. doi:10.1038/s42949-021-00018-w

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., et al. (2013). "Stewardship of the Biosphere in the Urban Era," in *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment*. Editors T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. I. McDonald, et al. (Dordrecht: Springer Netherlands), 719–746. doi:10.1007/978-94-007-7088-1_33

Elton, C. S. (1958). *The Ecology of Invasions by Animals and Plants*. Chicago, Illinois, USA: University of Chicago Press.

Epstein, G., Vogt, J. M., Mincey, S. K., Cox, M., and Fischer, B. (2013). Missing Ecology: Integrating Ecological Perspectives with the Social-Ecological System Framework. *Int. J. Commons* 7, 432–453. doi:10.18352/ijc.371

Ernstson, H., Barthel, S., Andersson, E., and Borgström, S. (2010). Scale-Crossing Brokers and Network Governance of Urban Ecosystem Services: The Case of Stockholm *Ecol. Soc.* 15 (4). doi:10.5751/ES-03692-150428

Essl, F., Lenzner, B., Bacher, S., Bailey, S., Capinha, C., Daehler, C., et al. (2020). Drivers of Future Alien Species Impacts: An Expert-based Assessment. *Glob. Change Biol.* 26, 4880–4893. doi:10.1111/gcb.15199

Evers, C. R., Wardropper, C. B., Branoff, B., Granek, E. F., Hirsch, S. L., Link, T. E., et al. (2018). The Ecosystem Services and Biodiversity of Novel Ecosystems: A Literature Review. *Glob. Ecol. Conservation* 13, e00362. doi:10.1016/j.gecco.2017.e00362

Fabinyi, M., Evans, L., and Foale, S. J. (2014). Social-ecological Systems, Social Diversity, and Power: Insights from Anthropology and Political Ecology. *Ecol. Soc.* 19 (4), 8. doi:10.5751/ES-07029-190428

Feola, G. (2015). Societal Transformation in Response to Global Environmental Change: A Review of Emerging Concepts. *Ambio* 44 (5), 376–390. doi:10.1007/s13280-014-0582-z

Fishman, R. (1982). *Urban Utopias in the Twentieth century: Ebenezer Howard, Frank Lloyd Wright, Le Corbusier*. Cambridge, MA, USA: MIT Press.

Folke, C. (2016). Resilience (Republished). *E&S* 21, 444. doi:10.5751/ES-09088-210444

Forman, R. T. T., and Godron, M. (1981). Patches and Structural Components for a Landscape Ecology. *BioScience* 31 (10), 733–740. doi:10.2307/1308780

Frank, B., Delano, D., and Caniglia, B. (2017). Urban Systems: A Socio-Ecological System Perspective. *Sij* 1 (1), 1. doi:10.15406/sij.2017.01.00001

Frantzeskaki, N., McPhearson, T., Collier, M. J., Kendal, D., Bulkeley, H., Dumitru, A., et al. (2019). Nature-based Solutions for Urban Climate Change Adaptation:

Linking Science, Policy, and Practice Communities for Evidence-Based Decision-Making. *BioScience* 69, 455–466. doi:10.1093/biosci/biz042

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

Gandy, M. (2016). Unintentional Landscapes. *Landscape Res.* 41, 433–440. doi:10.1080/01426397.2016.1156069

Geist, C., and Galatowitsch, S. M. (1999). Reciprocal Model for Meeting Ecological and Human Needs in Restoration Projects. *Conservation Biol.* 13, 970–979. doi:10.1046/j.1523-1739.1999.98074.x

Glaser, M., Krause, G., Ratter, B., and Welp, M. (2008). Human/Nature Interaction in the Anthropocene Potential of Social-Ecological Systems Analysis. *GAIA - Ecol. Perspect. Sci. Soc.* 17, 77–80. doi:10.14512/gaia.17.1.18

Gobster, P. H. (2010). Urban Ecological Restoration. *Nat. Cult.* 5 (3), 227–230. doi:10.3167/nc.2010.050301

Gómez-Baggethun, E., Gren, Å., Barton, D. N., Langemeyer, McPhearson, J. T., McPhearson, T., O'Farrell, P., et al. (2013). "Urban Ecosystem Services," in *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*. Editors T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, and R. I. McDonald (Dordrecht: Springer Netherlands), 175–251. doi:10.1007/978-94-007-7088-1_11

Görg, C., Brand, U., Haberl, H., Hummel, D., Jahn, T., and Liehr, S. (2017). Challenges for Social-Ecological Transformations: Contributions from Social and Political Ecology. *Sustainability* 9, 1045. doi:10.3390/su9071045

Gould, S. J. (1998). An Evolutionary Perspective on Strengths, Fallacies, and Confusions in the Concept of Native Plants. *Arnoldia* 58, 3–10.

Grabowski, Z. J., Matsler, A. M., Thiel, C., McPhillips, L., Hum, R., Bradshaw, A., et al. (2017). Infrastructures as Socio-Eco-Technical Systems: Five Considerations for Interdisciplinary Dialogue. *J. Infrastructure Syst.* 23, 02517002. doi:10.1061/(asce)is.1943-555x.0000383

Grimm, N. B., Morgan Grove, J., Pickett, S. T. A., and Redman, C. L. (2000). Integrated Approaches to Long-TermStudies of Urban Ecological Systems. *BioScience* 50, 571–584. doi:10.1641/0006-3568(2000)050[0571:iatlto]2.0.co;2

Haase, D., Frantzeskaki, N., Elmqvist, T., and Frantzeskaki, N. (2014). Ecosystem Services in Urban Landscapes: Practical Applications and Governance Implications. *Ambio* 43 (4), 407–412. doi:10.1007/s13280-014-0503-1

Haraway, D. (2003). *The Companion Species Manifesto: Dogs, People, and Significant Otherness*. Chicago, Illinois, USA: Prickly Paradigm Press.

Haraway, D. J. (2016). *Staying with the Trouble: Making Kin in the Chthulucene*. Durham, NC, USA: Duke University Press.

Herron, R. (1966). Walking City on the Ocean. The Museum of Modern Art. Available at: https://www.moma.org/collection/works/814

Higgs, E. (2012). Changing Nature: Novel Ecosystems, Intervention, and Knowing when to Step Back. *Sustainability Sci.*, 383–398. doi:10.1007/978-1-4614-3188-6_18

Higgs, E. (2017). Novel and Designed Ecosystems. *Restor Ecol.* 25, 8–13. doi:10.1111/rec.12410

Hobbs, R. J., Hallett, L. M., Ehrlich, P. R., and Mooney, H. A. (2011). Intervention Ecology: Applying Ecological Science in the Twenty-First Century. *BioScience* 61, 442–450. doi:10.1525/bio.2011.61.6.6

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annu. Rev. Ecol. Syst.* 4, 1–23. doi:10.1146/annurev.es.04.110173.000245

Hou, J. (2006). Hybrid Landscapes: Toward an Inclusive Ecological Urbanism on Seattle's central Waterfront. *94th ACSA Annu. Meet. Proc. Getting Real.* Available at: https://www.academia.edu/1934001/Hybrid_Landscapes_Toward_an_Inclusive_Ecological_Urbanism_on_Seattle_s_Central_Waterfront (Accessed August 18, 2021).

Houston, D., Hillier, J., MacCallum, D., Steele, W., and Byrne, J. (2018). Make Kin, Not Cities! Multispecies Entanglements and 'becoming-World' in Planning Theory. *Plann. Theor.* 17, 190–212. doi:10.1177/1473095216688042

Hoyer, J., and Almeida, N. (Editors) (2021). *The Social Movement Archive* (Sacramento, CA: Litwin Books).

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., and Yalcin, R. (2009). Adaptive Water Governance: Assessing the Institutional Prescriptions of Adaptive (Co-)management from a Governance Perspective and Defining a Research Agenda. *E&S* 14, 126. doi:10.5751/ES-02827-140126

Hustak, C., and Myers, N. (2012). Involutionary Momentum: Affective Ecologies and the Sciences of Plant/insect Encounters. *Differences* 23, 74–118. doi:10.1215/10407391-1892907

Hyvärinen, P. (2019). Beekeeping Expertise as Situated Knowing in Precarious Multispecies Livelihoods. *Sosiologia* 56, 365–381.

Ingalls, M. L. (2017). Not just Another Variable: Untangling the Spatialities of Power in Social–Ecological Systems. *Ecol. Soc.* 22 (3), 320. doi:10.5751/ES-09543-220320

Intergovernmental Panel on Climate Change (2021). "Climate Change 2021: The Physical Science Basis," in *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Editors V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, et al. (Cambridge, UK: Cambridge University Press).

Johnson, M. T. J., Thompson, K. A., and Saini, H. S. (2015). Plant Evolution in the Urban Jungle. *Am. J. Bot.* 102, 1951–1953. doi:10.3732/ajb.1500386

Jon, I. (2020). Deciphering Posthumanism: Why and How it Matters to Urban Planning in the Anthropocene. *Plann. Theor.* 19, 392–420. doi:10.1177/1473095220912770

Jorgensen, A., and 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 (3), 338–363. doi:10.3167/nc.2010.050307

Kalarus, K., Halecki, W., and Skalski, T. (2019). Both semi-natural and Ruderal Habitats Matter for Supporting Insect Functional Diversity in an Abandoned Quarry in the City of Kraków (S Poland). *Urban Ecosyst.* 22, 943–953. doi:10.1007/s11252-019-00869-3

Keeler, B. L., Hamel, P., McPhearson, T., Hamann, M. H., Donahue, M. L., Meza Prado, K. A., et al. (2019). Social-ecological and Technological Factors Moderate the Value of Urban Nature. *Nat. Sustain.* 2, 29–38. doi:10.1038/s41893-018-0202-1

Kennedy, C., Pincetl, S., and Bunje, P. (2011). The Study of Urban Metabolism and its Applications to Urban Planning and Design. *Environ. Pollut.* 159, 1965–1973. doi:10.1016/j.envpol.2010.10.022

Kerstes, N. A. G., Breeschoten, T., Kalkman, V. J., and Schilthuizen, M. (2019). Snail Shell Colour Evolution in Urban Heat Islands Detected via Citizen Science. *Commun. Biol.* 2, 1–11. doi:10.1038/s42003-019-0511-6

Khew, J. Y. T., Yokohari, M., and Tanaka, T. (2014). Public Perceptions of Nature and Landscape Preference in singapore. *Hum. Ecol.* 42 (6), 979–988. doi:10.1007/s10745-014-9709-x

Kimmerer, R. (2011). "Restoration and Reciprocity: The Contributions of Traditional Ecological Knowledge," in *Human Dimensions of Ecological Restoration: Integrating Science, Nature, and Culture Society for Ecological Restoration.* Editors D. Egan, E. E. Hjerpe, and J. Abrams (Washington, D.C.: Island Press/Center for Resource Economics), 257–276. doi:10.5822/978-1-61091-039-2_18

Kimmerer, R. W. (2015). *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Minneapolis, Minnesota, USA: Milkweed Editions.

Kirksey, E. (2014). *The Multispecies Salon*. Durham, NC, USA: Duke University Press Books.

Kremer, P., Hamstead, Z. A., and McPhearson, T. (2016). The Value of Urban Ecosystem Services in New York City: A Spatially Explicit Multicriteria Analysis of Landscape Scale Valuation Scenarios. *Environ. Sci. Pol.* 62, 57–68. doi:10.1016/j.envsci.2016.04.012

Krieger, M. H. (1974). Some New Directions for Planning Theories. *J. Am. Inst. Planners* 40, 156–163. doi:10.1080/01944367408977465

Ksiazek-Mikenas, K., and Köhler, M. (2018). Traits for Stress-Tolerance Are Associated with Long-Term Plant Survival on green Roofs. *J. Urban Ecol.* 4. doi:10.1093/jue/juy016

Kwok, R. (2018). News Feature: Accidental Urban Oases. *Proc. Natl. Acad. Sci. USA* 115, 4800–4804. doi:10.1073/pnas.1806197115

Lachmund, J. (2013). "The Invention of the Ruderal Area: Urban Ecology and the Struggle for Wasteland protection in West-berlin," in RC21-conference (Berlin: Maastricht University).

Lachmund, J. (2003). Exploring the City of Rubble: Botanical Fieldwork in Bombed Cities in Germany after World War II. *Osiris* 18, 234–254. doi:10.1086/649386

Langemeyer, J., Gómez-Baggethun, E., Haase, D., Scheuer, S., and Elmqvist, T. (2016). Bridging the gap between Ecosystem Service Assessments and Land-Use Planning through Multi-Criteria Decision Analysis (MCDA). *Environ. Sci. Pol.* 62, 45–56. doi:10.1016/j.envsci.2016.02.013

Larson, B. M. H. (2007). Who's Invading what? Systems Thinking about Invasive Species. *Can. J. Plant Sci.* 87, 993–999. doi:10.4141/CJPS07116

Laukyte, M. (2016). *Against Human Exceptionalism: Environmental Ethics and the Machine Question*. Berlin, Germany: Springer International Publishing.

Li, J., and Nassauer, J. I. (2020). Cues to Care: A Systematic Analytical Review. *Landscape Urban Plann.* 201, 103821. doi:10.1016/j.landurbplan.2020.103821

Lidström, S., and West, S. (2017). An Interdisciplinary Perspective on Invasive Alien Species. *PLOS Ecol.* Available at: https://theplosblog.plos.org/2017/10/an-interdisciplinary-perspective-on-invasive-alien-species/(Accessed December 20, 2019).

Lidström, S., West, S., Katzschner, T., Pérez-Ramos, M. I., and Twidle, H. (2016). Invasive Narratives and the Inverse of Slow Violence: Alien Species in Science and Society. *Environ. Humanities* 7, 1–40. doi:10.1215/22011919-3616317

Lin, J., and Robinson, P. (2012). "Spatial Disparities in the Expansion of the Chinese Ethnoburb of Los Angeles," in *The Urban Sociology Reader*. Editors J. Lin and C. Mele (Oxfordshire, England, UK: Routledge).

Locke, D. H., and McPhearson, T. (2018). Urban Areas Do Provide Ecosystem Services. *Front. Ecol. Environ.* 16 (4), 203–205. doi:10.1002/fee.1796

Longcore, T., Mattoni, R., Pratt, G., and Rich, C. (1997). *On the Perils of Ecological Restoration: Lessons from the el segundo Blue Butterfly*. Occidental College, CA: 2nd Interface Between Ecology and Land Development in California.

Lorimer, J. (2012). Multinatural Geographies for the Anthropocene. *Prog. Hum. Geogr.* 36, 593–612. doi:10.1177/0309132511435352

Luchkova, V. I. (2011). *The History of the Chinese City. Town-Planning, Architecture, Landscape Art*. Khabarovsk, Russia: Pacific National University Publishing.

Mabey, R., and Sinclair, I. (2010). *The Unofficial Countryside*. Beaminster, UK: Little Toller Books.

MacDougall, A. S., and Turkington, R. (2005). Are Invasive Species the Drivers or Passengers of Change in Degraded Ecosystems? *Ecology* 86, 42–55. doi:10.1890/04-0669

Maier, C., Hebermehl, W., Grossmann, C. M., Loft, L., Mann, C., and Hernández-Morcillo, M. (2021). Innovations for Securing forest Ecosystem Service Provision in Europe - A Systematic Literature Review. *Ecosystem Serv.* 52, 101374. doi:10.1016/j.ecoser.2021.101374

Malik, M. I., Mahmood, S., Yasin, G., and Bashir, N. (2012). Oxalis Corniculata as a Successful Lawn weed: A Study of Morphological Variation from Contrasting Habitats. *Pakistan J. Bot.* 44 (1), 407–411.

Manfredo, M. J., Teel, T. L., and Dietsch, A. M. (2016). Implications of Human Value Shift and Persistence for Biodiversity Conservation. *Conservation Biol.* 30, 287–296. doi:10.1111/cobi.12619

Manring, S. L. (2007). Creating and Managing Interorganizational Learning Networks to Achieve Sustainable Ecosystem Management. *Organ. Environ.* 20 (3), 325–346. doi:10.1177/1086026607305738

Marder, M. (2012). Plant Intentionality and the Phenomenological Framework of Plant Intelligence. *Plant Signaling Behav.* 7, 1365–1372. doi:10.4161/psb.21954

Marshall, S. (2008). *Cities Design and Evolution*. Oxfordshire, England, UK: Routledge.

Marshall, V. J., Cadenasso, M. L., McGrath, B. P., and Pickett, S. T. A. (2020). *Patch Atlas: Integrating Design Practices and Ecological Knowledge for Cities as Complex Systems*. London, England: Yale University Press.

Marzluff, J. M., and Rodewald, A. D. (2008). Conserving Biodiversity in Urbanizing Areas: Nontraditional Views from a Bird's Perspective. *Cate* 1, 1–27. doi:10.15365/cate.1262008

Mastnak, T., Elyachar, J., and Boellstorff, T. (2014). Botanical Decolonization: Rethinking Native Plants. *Environ. Plan. D* 32, 363–380. doi:10.1068/d13006p

McCay, B. (2000). Edges, fields and Regions (Presidential Address, Part II, IASCP 2000 Conference, Bloomington, Indiana). *Common Property Resource Dig.* 54, 6–8.

McClintock, N., Cooper, J., and Khandeshi, S. (2013). Assessing the Potential Contribution of Vacant Land to Urban Vegetable Production and Consumption in Oakland, California. *Landscape Urban Plann.* 111, 46–58. doi:10.1016/j.landurbplan.2012.12.009

McDonnell, M. J., and Hahs, A. K. (2015). Adaptation and Adaptedness of Organisms to Urban Environments. *Annu. Rev. Ecol. Evol. Syst.* 46, 261–280. doi:10.1146/annurev-ecolsys-112414-054258

McFarlane, C. (2009). Translocal Assemblages: Space, Power and Social Movements. *Geoforum* 40 (4), 561–567. doi:10.1016/j.geoforum.2009.05.003

McGrath, B., and Pickett, S. T. A. (2011). The Metacity: A Conceptual Framework for Integrating Ecology and Urban Design. *Challenges* 2, 55–72. doi:10.3390/challe2040055

McHale, M., Pickett, S., Barbosa, O., Bunn, D., Cadenasso, M., Childers, D., et al. (2015). The New Global Urban Realm: Complex, Connected, Diffuse, and Diverse Social-Ecological Systems. *Sustainability* 7, 5211–5240. doi:10.3390/su7055211

McHarg, I. L. (1969). *Design with Nature*. New York: American Museum of Natural History.

McKinney, M. L. (2008). Effects of Urbanization on Species Richness: A Review of Plants and Animals. *Urban Ecosyst.* 11, 161–176. doi:10.1007/s11252-007-0045-4

McKinney, M. L. (2006). Urbanization as a Major Cause of Biotic Homogenization. *Biol. Conservation* 127, 247–260. doi:10.1016/j.biocon.2005.09.005

McKinney, M. L. (2002). Urbanization, Biodiversity, and Conservation. *BioScience* 52, 883–890. doi:10.1641/0006-3568(2002)052[0883:ubac]2.0.co;2

McLain, R. J., Hurley, P. T., Emery, M. R., and Poe, M. R. (2014). Gathering "Wild" Food in the City: Rethinking the Role of Foraging in Urban Ecosystem Planning and Management. *Local Environ.* 19, 220–240. doi:10.1080/13549839.2013.841659

McMillen, H. L., Campbell, L. K., Svendsen, E. S., Kealiikanakaoleohaililani, K., Francisco, K. S., and Giardina, C. P. (2020). Biocultural Stewardship, Indigenous and Local Ecological Knowledge, and the Urban crucible. *E&S* 25 (2), 9. doi:10.5751/ES-11386-250209

McPhearson, T., Kremer, P., and Hamstead, Z. A. (2013). Mapping Ecosystem Services in New York City: Applying a Social-Ecological Approach in Urban Vacant Land. *Ecosystem Serv.* 5, 11–26. doi:10.1016/j.ecoser.2013.06.005

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., et al. (2016). Advancing Urban Ecology toward a Science of Cities. *BioScience* 66, 198–212. doi:10.1093/biosci/biw002

Millard, A. (2004). Indigenous and Spontaneous Vegetation: Their Relationship to Urban Development in the City of Leeds, UK. *Urban For. Urban Green.* 3, 39–47. doi:10.1016/j.ufug.2004.04.004

Miller, M. A., Douglass, M., and Rigg, J. (2020). Governing Resilient Cities for Planetary Flourishing in the Asia-Pacific. *Urban Stud.* 57, 1359–1371. doi:10.1177/0042098020903955

Monstadt, J. (2009). Conceptualizing the Political Ecology of Urban Infrastructures: Insights from Technology and Urban Studies. *Environ. Plan. A.* 41 (8), 1924–1942. doi:10.1068/a4145

Moraci, F., Errigo, M. F., Fazia, C., Campisi, T., and Castelli, F. (2020). Cities under Pressure: Strategies and Tools to Face Climate Change and Pandemic. *Sustainability* 12, 7743. doi:10.3390/su12187743

Morgan, D. (2019a). "Multispecies Planning: Locating Nonhuman Entanglements in Oyster Restoration Policy on the Massachusetts Coast,". Thesis (Medford, MA, USA: Tufts University). ResearchGate. doi:10.13140/RG.2.2.20422.09287

Morgan, D. (2019). Reworlding Environmental Policy: How Oysters Come to Matter. *Land Exchange Res. Group*. Available at: https://lex.landscaperesearch.org/content/reworlding-environmental-policy-how-oysters-come-to-matter/ (Accessed March 8, 2021).

Morse, N. B., Pellissier, P. A., Cianciola, E. N., Brereton, R. L., Sullivan, M. M., Shonka, N. K., et al. (2014). Novel Ecosystems in the Anthropocene: A Revision of the Novel Ecosystem Concept for Pragmatic Applications. *E&S* 19, 12. doi:10.5751/ES-06192-190212

Mostafavi, M., and Doherty, G. (Editors) (2010). *Ecological Urbanism* (Zurich, Switzerland: Lars Muller).

Moughtin, C. (1996). *Urban Design: Green Dimensions*. Oxford, UK: Butterworth Architecture.

Munshi-South, J., and Kharchenko, K. (2010). Rapid, Pervasive Genetic Differentiation of Urban white-footed Mouse (Peromyscus Leucopus) Populations in New York City. *Mol. Ecol.* 19, 4242–4254. doi:10.1111/j.1365-294X.2010.04816.x

Münster, U., and Locke, P. (2015). *Multispecies Ethnography*. Oxford: Oxford University Bibliographies Online. doi:10.1093/OBO/9780199766567-0130

Nadasdy, P. (2007). "Adaptive Co-management and the Gospel of Resilience," in *Adaptive Co-management: Collaboration, Learning, and Multi-Level Governance*. Editors D. Armitage, F. Berkes, and N. Doubleday (Vancouver, Canada: University of British Columbia Press), 208–227.

Naess, A. (1988). Deep Ecology and Ultimate Premises. *Ecologist* 18, 128–131.

Nassauer, J. I. (1995). Messy Ecosystems, Orderly Frames. *Landscape Jrnl.* 14, 161–170. doi:10.3368/lj.14.2.161

Nassauer, J. I., and Raskin, J. (2014). Urban Vacancy and Land Use Legacies: A Frontier for Urban Ecological Research, Design, and Planning. *Landscape Urban Plann.* 125, 245–253. doi:10.1016/j.landurbplan.2013.10.008

Naveh, Z. (2000). What Is Holistic Landscape Ecology? A Conceptual Introduction. *Landscape Urban Plann.* 50 (1), 7–26. doi:10.1016/S0169-2046(00)00077-3

Newman, G. D., Bowman, A. O. M., Jung Lee, R., and Kim, B. (2016). A Current Inventory of Vacant Urban Land in America. *J. Urban Des.* 21, 302–319. doi:10.1080/13574809.2016.1167589

Newman, G., Park, Y., Bowman, A. O. M., and Lee, R. J. (2018). Vacant Urban Areas: Causes and Interconnected Factors. *Cities* 72, 421–429. doi:10.1016/j.cities.2017.10.005

Olsson, P., Folke, C., and Berkes, F. (2004). Adaptive Comanagement for Building Resilience in Social?Ecological Systems. *Environ. Manage.* 34, 75–90. doi:10.1007/s00267-003-0101-7

Orion, T. (2015). *Beyond the War on Invasive Species*. Hartford, Vermont, USA: Chelsea Green Publishing.

Pacione, M. (2009). *Urban Geography: A Global Perspective*. Oxfordshire, England, UK: Routledge.

Pandit, A., Minné, E. A., Li, F., Brown, H., Jeong, H., James, J.-A. C., et al. (2017). Infrastructure Ecology: an Evolving Paradigm for Sustainable Urban Development. *J. Clean. Prod.* 163, S19–S27. doi:10.1016/j.jclepro.2015.09.010

Paperson, L. (2014). A Ghetto Land Pedagogy: An Antidote for Settler Environmentalism. *Environ. Educ. Res.* 20, 115–130. doi:10.1080/13504622.2013.865115

Pearce, F. (2016). *The New Wild: Why Invasive Species Will Be Nature's Salvation*. Boston: Beacon Press.

Pellegrini, P., and Baudry, S. (2014). Streets as New Places to Bring Together Both Humans and Plants: Examples from Paris and Montpellier (France). *Soc. Cult. Geogr.* 15, 871–900. doi:10.1080/14649365.2014.974067

Peponis, J. (1989). Space, Culture and Urban Design in Late Modernism and after. *Ekistics* 56 (334/335), 93–108.

Phillips, D. (2003). *The Truth of Ecology: Nature, Culture, and Literature in America*. Oxford: Oxford University Press.

Pickett, S. T. A., Grove, J. M., LaDeau, S. L., Rosi, E. J., and Cadenasso, M. L. (2020). "Urban Ecology as an Integrative Science and Practice," in *Urban Ecology: Its Nature and Challenges*. Editor P. Barbosa, 122–143. doi:10.1079/9781789242607.0122

Platt, R. H. (Editor) (1994). *The Ecological City: Preserving and Restoring Urban Biodiversity* (Amherst, MA, USA: University of Massachusetts Press).

Plieninger, T., van der Horst, D., Schleyer, C., and Bieling, C. (2014). Sustaining Ecosystem Services in Cultural Landscapes. *Ecol. Soc.* 19 (2), 9. doi:10.5751/es-06159-190259

Plumwood, V. (2009). Nature in the Active Voice. *Ecol. Humanities* 46. doi:10.22459/ahr.46.2009.10

Plumwood, V. (1986). Ecofeminism: An Overview and Discussion of Positions and Arguments. *Australas. J. Philos.* 64, 120–138. doi:10.1080/00048402.1986.9755430

Porebska, G., and Ostrowska, A. (1999). Heavy Metal Accumulation in Wild Plants: Implications for Phytoremediation. *Pol. J. Environ. Stud.* 8, 433–442.

Potgieter, L. J., Gaertner, M., O'Farrell, P. J., and Richardson, D. M. (2019). Perceptions of Impact: Invasive Alien Plants in the Urban Environment. *J. Environ. Manage.* 229, 76–87. doi:10.1016/j.jenvman.2018.05.080

Randolph, J. R. (2003). *Environmental Land Use Planning and Management*. Washington, D.C.: Island Press.

Randrup, T. B., Buijs, A., Konijnendijk, C. C., and Wild, T. (2020). Moving beyond the Nature-Based Solutions Discourse: Introducing Nature-Based Thinking. *Urban Ecosyst.* 23, 919–926. doi:10.1007/s11252-020-00964-w

Ratzlaff, E. D. (1970). "Applications of Engineering Systems. Analysis to the Human Social-Ecological System,". Thesis (Davis: University of California).

Reyers, B., Folke, C., Moore, M.-L., Biggs, R., and Galaz, V. (2018). Social-ecological Systems Insights for Navigating the Dynamics of the Anthropocene. *Annu. Rev. Environ. Resour.* 43, 267–289. doi:10.1146/annurev-environ-110615-085349

Reyes-García, V., Fernández-Llamazares, Á., McElwee, P., Molnár, Z., Öllerer, K., Wilson, S. J., et al. (2019). The Contributions of Indigenous Peoples and Local Communities to Ecological Restoration. *Restor Ecol.* 27, 3–8. doi:10.1111/rec.12894

Richardson, D. M., Allsopp, N., D'antonio, C. M., Milton, S. J., and Rejmánek, M. (2000). Plant Invasions - the Role of Mutualisms. *Biol. Rev.* 75, 65–93. doi:10.1017/s0006323199005435

Riley, C. B., Herms, D. A., and Gardiner, M. M. (2018b). Exotic Trees Contribute to Urban forest Diversity and Ecosystem Services in Inner-City Cleveland, OH. *Urban For. Urban Green.* 29, 367–376. doi:10.1016/j.ufug.2017.01.004

Riley, C., Perry, K., Ard, K., and Gardiner, M. (2018a). Asset or Liability? Ecological and Sociological Tradeoffs of Urban Spontaneous Vegetation on Vacant Land in Shrinking Cities. *Sustainability* 10, 2139. doi:10.3390/su10072139

Robinson, J. M., Gellie, N., MacCarthy, D., Mills, J. G., O'Donnell, K., and Redvers, N. (2021). Traditional Ecological Knowledge in Restoration Ecology: A Call to Listen Deeply, to Engage with, and Respect Indigenous Voices. *Restor Ecol.* 29, e13381. doi:10.1111/rec.13381

Robinson, S. L., and Lundholm, J. T. (2012). Ecosystem Services provided by Urban Spontaneous Vegetation. *Urban Ecosyst.* 15, 545–557. doi:10.1007/s11252-012-0225-8

Rozzi, R. (2013). "Biocultural Ethics: From Biocultural Homogenization toward Biocultural Conservation," in *Linking Ecology and Ethics for a Changing World: Values, Philosophy, and Action*. Editors R. Rozzi, S. T. A. Pickett, C. Palmer, J. J. Armesto, and J. B. Callicott (Dordrecht: Springer Netherlands), 9–32. doi:10.1007/978-94-007-7470-4_2

Rupprecht, C. D. D., Byrne, J. A., Garden, J. G., and Hero, J.-M. (2015). Informal Urban green Space: A Trilingual Systematic Review of its Role for Biodiversity and Trends in the Literature. *Urban For. Urban Green.* 14, 883–908. doi:10.1016/j.ufug.2015.08.009

Rupprecht, C. D. D., and Byrne, J. A. (2014). Informal Urban green-space: Comparison of Quantity and Characteristics in Brisbane, Australia and Sapporo, Japan. *PLOS ONE* 9, e99784. doi:10.1371/journal.pone.0099784

Rupprecht, C. D. D., Vervoort, J., Berthelsen, C., Mangnus, A., Osborne, N., Thompson, K., et al. (2020). Multispecies Sustainability. *Glob. Sustain.* 3. doi:10.1017/sus.2020.28

Safdie, M., Kohn, W., and Mcknight, G. D. (1997). *The City after the Automobile: Past, Present, and Future*. New York: Basic Books.

Salmón, E. (2000). Kincentric Ecology: Indigenous Perceptions of the Human-Nature Relationship. *Ecol. Appl.* 10, 1327–1332. doi:10.2307/2641288

Samuelsson, K., Giusti, M., Peterson, G. D., Legeby, A., Brandt, S. A., and Barthel, S. (2018). Impact of Environment on People's Everyday Experiences in Stockholm. *Landscape Urban Plann.* 171, 7–17. doi:10.1016/j.landurbplan.2017.11.009

Sanderson, K. (2008). Weed's Seeds Evolve Quickly in the City. *Nature*. doi:10.1038/news.2008.639

Sarkar, S. (2005). *Biodiversity and Environmental Philosophy: An Introduction*. Cambridge, UK: Cambridge University Press.

Schalk, M. (2014). The Architecture of Metabolism. Inventing a Culture of Resilience. *Arts* 3, 279–297. doi:10.3390/arts3020279

Schell, C. J., Dyson, K., Fuentes, T. L., Des Roches, S., Harris, N. C., Miller, D. S., et al. (2020). The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments. *Science* 369, 6510. doi:10.1126/science.aay4497

Schuyler, P. D. (1988). *The New Urban Landscape: The Redefinition of City Form in Nineteenth-century America*. Baltimore, Maryland, USA: Johns Hopkins University Press.

Seed, J., and Macy, J. (2007). *Thinking like a Mountain: Towards a council of All Beings*. Gabriola, Canada: New Catalyst Books.

Setiadi, R., Nadhiroh, S. Z., and Rupprecht, C. (2021). A Regulatory Framework Assessment on Multispecies Urban Planning in Indonesia: A Case Study of Two Indonesian Cities in Java and Borneo. *Res. Square*. doi:10.21203/rs.3.rs-715509/v1

Seto, K. C., Güneralp, B., and Hutyra, L. R. (2012). Global Forecasts of Urban Expansion to 2030 and Direct Impacts on Biodiversity and Carbon Pools. *Proc. Natl. Acad. Sci.* 109, 16083–16088. doi:10.1073/pnas.1211658109

Shabecoff, P. (2003). *A Fierce green Fire: The American Environmental Movement*. Washington: Island Press.

Shingne, M. C. (2020). The more-Than-human Right to the City: A Multispecies Reevaluation. *J. Urban Aff.* 2020, 1–19. doi:10.1080/07352166.2020.1734014

Simberloff, D., Souza, L., Nuñez, M. A., Barrios-Garcia, M. N., and Bunn, W. (2012). The Natives Are Restless, but Not Often and Mostly when Disturbed. *Ecology* 93, 598–607. doi:10.1890/11-1232.1

Solomon, D. A. (2019). "Soil in the City: The Socio-Environmental Substrate," in *Field to Palette: Dialogues on Soil and Art in the Anthropocene*. Editors A. Toland, J. Stratton Noller, and G. Wessolek (Boca Raton, Florida, USA: CRC Press), 605–624.

Soulé, M. E. (1985). What Is Conservation Biology? *BioScience* 35, 727–734. doi:10.2307/1310054

Steele, W., Wiesel, I., and Maller, C. (2019). More-Than-human Cities: Where the Wild Things Are. *Geoforum* 106, 411–415. doi:10.1016/j.geoforum.2019.04.007

Steiner, F. (2011). Landscape Ecological Urbanism: Origins and Trajectories. *Landscape Urban Plann.* 100 (4), 333–337. doi:10.1016/j.landurbplan.2011.01.020

Sterling, E. J., Filardi, C., Toomey, A., Sigouin, A., Betley, E., Gazit, N., et al. (2017). Biocultural Approaches to Well-Being and Sustainability Indicators across Scales. *Nat. Ecol. Evol.* 1, 1798–1806. doi:10.1038/s41559-017-0349-6

Stoetzer, B. (2018). Ruderal Ecologies: Rethinking Nature, Migration, and the Urban Landscape in Berlin. *Cult. Anthropol.* 33, 295–323. doi:10.14506/ca33.2.09

Sukopp, H., and Werner, P. (1983). "Urban Environments and Vegetation," in *Man's Impact on Vegetation*. Editors W. Holzner, M. J. A. Werger, and I. Ikusima (Berlin, Germany: Springer), 247–260. doi:10.1007/978-94-009-7269-8_19

Svendsen, E. S., and Campbell, L. (2008). Urban Ecological Stewardship: Understanding the Structure, Function and Network of Community-Based Urban Land Management. *Cate* 1, 1–31. doi:10.15365/cate.1142008

Tceluiko, D. (2019). Influence of Shamanism, Taoism, Buddhism and Confucianism on Development of Traditional Chinese Gardens. *IOP Conf. Ser. Mater. Sci. Eng.* 687, 055041. doi:10.1088/1757-899X/687/5/055041

Thomas, C. D. (2013). The Anthropocene Could Raise Biological Diversity. *Nature* 502, 7. doi:10.1038/502007a

Thompson, K., and McCarthy, M. A. (2008). Traits of British Alien and Native Urban Plants. *J. Ecol.* 96, 853–859. doi:10.1111/j.1365-2745.2008.01383.x

Thomsen, B., Thomsen, J., Copeland, K., Coose, S., Arnold, E., Bryan, H., et al. (2021). Multispecies Livelihoods: a Posthumanist Approach to Wildlife Ecotourism that Promotes Animal Ethics. *J. Sustain. Tourism* 2021, 1–19. doi:10.1080/09669582.2021.1942893

Threlfall, C. G., and Kendal, D. (2018). The Distinct Ecological and Social Roles that Wild Spaces Play in Urban Ecosystems. *Urban For. Urban Green.* 29, 348–356. doi:10.1016/j.ufug.2017.05.012

Tieskens, K. F., Schulp, C. J. E., Levers, C., Lieskovský, J., Kuemmerle, T., Plieninger, T., et al. (2017). Characterizing European Cultural Landscapes: Accounting for Structure, Management Intensity and Value of Agricultural and forest Landscapes. *Land Use Policy* 62, 29–39. doi:10.1016/j.landusepol.2016.12.001

Tredici, P. D. (2010). Spontaneous Urban Vegetation: Reflections of Change in a Globalized World. *Nat. Cult.* 5 (3), 299–315. doi:10.3167/nc.2010.050305

Tsing, A. (2013). "More-Than-human Sociality: A Call for Critical Description," in *Anthropology and Nature*. Editor K. Hastrup (Oxfordshire, England, UK: Routledge), 27–42.

Tsing, A., and Elkin, R. (2018). The Politics of the Rhizosphere. *Harv. Des. Mag.* 45. Available at: http://www.harvarddesignmagazine.org/issues/45/the-politics-of-the-rhizosphere (Accessed August 29, 2021).

Tsing, A. L., Mathews, A. S., and Bubandt, N. (2019). Patchy Anthropocene: Landscape Structure, Multispecies History, and the Retooling of Anthropology. *Curr. Anthropol.* 60, S186–S197. doi:10.1086/703391

Turner, N. J., Davidson-Hunt, I. J., and O'Flaherty, M. (2003). Living on the Edge: Ecological and Cultural Edges as Sources of Diversity for Social—Ecological Resilience. *Hum. Ecol.* 31, 439–461. doi:10.1023/a:1025023906459

Turo, K. J., and Gardiner, M. M. (2019). From Potential to Practical: Conserving Bees in Urban Public green Spaces. *Front. Ecol. Environ.* 17, 167–175. doi:10.1002/fee.2015

UN Secretary-General, and World Commission on Environment and Development (1987). Report of the World Commission on Environment and Development. Available at: https://digitallibrary.un.org/record/139811 (Accessed August 18, 2021).

United Nations Department of Economic and Social Affairs (2018). 68% of the World Population Projected to Live in Urban Areas by 2050, Says UN. Available at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html (Accessed August 19, 2021).

Uprety, Y., Asselin, H., Bergeron, Y., Doyon, F., and Boucher, J.-F. (2012). Contribution of Traditional Knowledge to Ecological Restoration: Practices and Applications. *Écoscience* 19, 225–237. doi:10.2980/19-3-3530

US Fish and Wildlife Service (2011). The Cost of Invasive Species. Available at: https://www.fws.gov/news/blog/index.cfm/2011/8/12/The-Cost-of-Invasive-Species (Accessed August 18, 2021).

Valéry, L., Fritz, H., and Lefeuvre, J.-C. (2013). Another Call for the End of Invasion Biology. *Oikos* 122 (8), 1143–1146. doi:10.1111/j.1600-0706.2013.00445.x

Vega, K. A., Schläpfer-Miller, J., and Kueffer, C. (2021). Discovering the Wild Side of Urban Plants through Public Engagement. *Plants People Planet.* 3, 389–401. doi:10.1002/ppp3.10191

Vierikko, K., Elands, B., Niemelä, J., Andersson, E., Buijs, A., Fischer, L. K., et al. (2016). Considering the Ways Biocultural Diversity Helps Enforce the Urban green Infrastructure in Times of Urban Transformation. *Curr. Opin. Environ. Sustainability* 22, 7–12. doi:10.1016/j.cosust.2017.02.006

Waldheim, C. (Editor) (2006). *The Landscape Urbanism Reader* (New York: Princeton Architectural Press).

Walker, B., Holling, C. S., Carpenter, S., and Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social–Ecological Systems. *Ecol. Soc.* 9 (2). doi:10.5751/ES-00650-090205

Weber, F., Kowarik, I., and Säumel, I. (2014). A Walk on the Wild Side: Perceptions of Roadside Vegetation beyond Trees. *Urban For. Urban Green.* 13, 205–212. doi:10.1016/j.ufug.2013.10.010

Wilkinson, C. (2012). Social-ecological Resilience: Insights and Issues for Planning Theory. *Plann. Theor.* 11, 148–169. doi:10.1177/1473095211426274

Williams, N. S. G., Hahs, A. K., and Vesk, P. A. (2015). Urbanisation, Plant Traits and the Composition of Urban Floras. *Perspect. Plant Ecol. Evol. Syst.* 17, 78–86. doi:10.1016/j.ppees.2014.10.002

Winchell, K. M., Reynolds, R. G., Prado-Irwin, S. R., Puente-Rolón, A. R., and Revell, L. J. (2016). Phenotypic Shifts in Urban Areas in the Tropical lizardAnolis Cristatellus. *Evolution* 70, 1009–1022. doi:10.1111/evo.12925

Wolch, J. (2002). Anima Urbis. *Prog. Hum. Geogr.* 26, 721–742. doi:10.1191/0309132502ph400oa

Wu, J. (2014). Urban Ecology and Sustainability: The State-Of-The-Science and Future Directions. *Landscape Urban Plann.* 125, 209–221. doi:10.1016/j.landurbplan.2014.01.018

Yang, L., Turo, K. J., Riley, C. B., Inocente, E. A., Tian, J., Hoekstra, N. C., et al. (2019). Can Urban Greening Increase Vector Abundance in Cities? the Impact of Mowing, Local Vegetation, and Landscape Composition on Adult Mosquito Populations. *Urban Ecosyst.* 22, 827–839. doi:10.1007/s11252-019-00857-7

Zhang, M., Song, K., and Da, L. (2020). The Diversity Distribution Pattern of Ruderal Community under the Rapid Urbanization in Hangzhou, East China. *Diversity* 12, 116. doi:10.3390/d12030116

Zhou, W., Pickett, S. T. A., and McPhearson, T. (2021). Conceptual Frameworks Facilitate Integration for Transdisciplinary Urban Science. *Npj Urban Sustain.* 1, 1–11. doi:10.1038/s42949-020-00011-9

Ziter, C., Graves, R. A., and Turner, M. G. (2017). How Do Land-Use Legacies Affect Ecosystem Services in United States Cultural Landscapes? *Landscape Ecol.* 32, 2205–2218. doi:10.1007/s10980-017-0545-4

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.