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Review

Opportunities for Biodiversity Conservation via Urban Ecosystem Regeneration

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Abstract: Conservation traditionally focuses on at-risk species and relatively intact ecosystems. As the human population and our global impact have risen, many more species and ecosystems are at risk and fewer intact ecosystems remain, with urbanization being a major contributing factor. Cities and their inhabitants are here to stay, and the prevalence of urbanization, often in the vicinity of areas of high conservation value, requires reconsideration of the conservation value of urban ecosystems and urban green spaces. Our aim is to explore the practical aspects of such actions. Urban ecosystem regeneration will require the incorporation of strategies for urban ecosystem regeneration into an overall conservation policy. The novel paradigm of urban ecosystem regeneration, advocated here, maximizes the capacity of urban spaces to support biodiversity while reducing undesirable outcomes and enhancing human wellbeing. The potential for cities to exacerbate biological invasion, climate change, and other ecosystem-degrading factors requires particular attention in devising a strategy for conservation in urban spaces, made essential by the predicted further spread of cities across the globe.

Keywords: urbanization; conservation; urban green spaces; urban ecosystem regeneration; invasive species

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1. Introduction

Human populations and cities are growing rapidly and are occupying ever-larger portions of the Earth's surface. Humans totaled at about 8 billion as of 2022, up from around 2.5 billion in 1950, and will reach close to 10 billion by 2050, according to United Nations estimates [1]. Urban populations have also increased rapidly. In 1800, less than 2.5 percent of the world's population lived in cities of 20,000 or more [2], reaching less than a third of humanity in 1950, and doubling by more than two-thirds one century later [3]. This growth is most evident in mid-income countries (Figure 1, light and dark blue) and is accelerating in low-income countries (green triangles).

To accommodate increases in urban populations, the land area devoted to cities has also been growing [4,5]. Just between 1970 and 2000, the global urban land area increased by 58,000 km^2, greater than the terrestrial area of Denmark, with a further increase of 12,568,000 km^2 possible by 2030, "with an estimate of 1,527,000 km^2 more likely." [6]. Urban area measured slightly over 0.6 million km^2, roughly 0.5 percent of the global land surface, in 2020 [7]. The urban footprint is predicted to continue expanding, roughly two- to five-fold by 2100, depending on the expansion scenario employed [7]. Since the 1990s, the total size of urban areas in the continental United States has exceeded that of national and state parks [4]. The negative impacts of urbanization are not limited to land conversion. To feed the growing urban (and non-urban) populations, an ever-expanding proportion of the Earth's land surface has been converted for agricultural uses, now exceeding 45 percent of habitable land [8]. Producing and transporting food and other resources to urban centers further contributes to the production of global climate gasses [9].

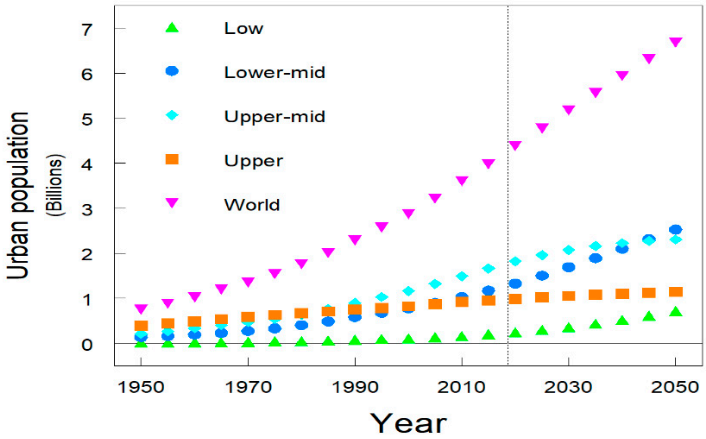

Figure 1. Urban human population between 1950 (actual, left of dotted vertical line) and 2050 (projected, right of line), from United Nations country-income categories. Data from [3].

Overall, the biomass of humans and their mammalian livestock now exceeds 1000 million metric tons, compared to only about 60 million tons for all wild mammals, terrestrial, and marine animals, combined [10]. Human-made mass such as buildings and roads now surpasses all global living biomass [11]. The continuing conversion of native habitats to ones dominated by human presence has proceeded more rapidly than previously predicted [12] and has had disastrous consequences for local and global biodiversity [13,14], which is predicted to continue to decline unless policies change [15,16]. In response to the realization of the dominance of human actions on global biodiversity [17], conservation biology emerged in the 1980s as a discipline focused on stopping, and ideally reversing, the decline in global biodiversity; the Society for Conservation Biology was established in 1985. Restoration ecology emerged in the 20th century to help sustain biodiversity by developing tools for restoring degraded ecosystems, with the Society for Ecological Restoration established in 1988. To study the structure and function of urban ecosystems, urban ecology arose as a discipline around the turn of the 21st century; the Society for Urban Ecology was established in 2009.

Urban environments are among the most extreme cases of human-constructed settings, and though they may provide a home to an unprecedented mix of species, they are relatively poorly studied [18]. Urbanization is part of the problem driving conservation efforts, and thus should also be part of the solution [19]. While recognizing the need for, and the primacy of, protecting biodiversity in relatively natural landscapes, we argue that the increasing growth of urban areas requires that (1) regenerating urban environments are recognized as ecosystems, albeit non-traditional and sometimes impoverished ones; (2) conservation efforts incorporate these urban ecosystems, e.g., [13,14,16]. The novel ecosystem concept [20], though not devised for urban settings [21], nor precisely defined [22], provides a viable framework for conservation in urban settings; (3) new approaches for urban ecosystem regeneration (UER) must be developed, since the magnitude of the human impact and the lack of traditional reference states preclude most customary conservation and restoration efforts in these ecosystems, e.g., [23,24]; and (4) the possible negative impacts on both urban and surrounding areas, such as the effects of invasive species [25] and climate change [26], must be given greater attention for deciding how to implement the approach. UER is used here to mean any human-directed activities intended to increase or conserve biodiversity, with a focus on native species, in urban ecosystems. This concept is expanded in Section 5. As of yet, ecologically oriented reviews of the direct and indirect impacts of urbanization have focused almost exclusively on the substantial and increasingly documented negative effects and rarely mention the possibility of positive effects. Our goal in this review is to explore the justification for, possible value of, and major concerns related to UER.

2. Urban Environments as Ecosystems

The term "ecosystem" has been variously used to indicate at least three distinct concepts: one centered on organisms, another on processes such as matter and energy flows, and a third that is location-based and centered on regional characteristics such as climate and biodiversity [27]. Humans have not traditionally been considered a proper component of any of these ecosystem concepts, leading to repeated calls to broaden the definition [17,28]. In settings other than urban environments, however, the role of human interaction with biodiversity and other ecosystem processes was nonetheless understood by the 1990s, e.g., [29], leading to the increasingly common use of the term "agroecosystem" and consideration of their value in conservation, e.g., [30]. Yet, other human-dominated environments, and especially cities, were not considered ecosystems worthy of ecological study or incorporation into conservation efforts until relatively recently.

As a whole, urban systems are not self-sustaining because they rely on the ongoing human provision of material inputs such as food and energy, many of which may arrive from far away. Moreover, particularly urban green spaces, such as lawns, rely on regular upkeep to maintain their socially preferred form. Nonetheless, this kind of active input and management is not unique to urban settings, which hold diverse mixes of native and non-native taxa [31]. For example, we are facing a "massive die-off" of Florida manatees (*Trichechus manatus latirostris*) because of starvation during the winter of 2021–2022; the US Fish and Wildlife Service and the Florida Fish and Wildlife Commission have engaged in a feeding effort [32]. Nearly 100,000 metric tons of lettuce and cabbage were fed that year, and "officials plan to review the situation annually to see how long the work should continue", with preparations being made and about twice as much food used in the winter of 2022–2023 [32,33]. In a more extreme example, artificial reefs are constructed around the world, either to replace damaged reefs or to produce additional habitat where none previously existed, in order to increase biodiversity and/or fishery yields, e.g., [34]. Furthermore, some urban ecosystems, such as wilderness parks, do not rely on such hands-on maintenance for their ecological function, and many populations of urban species self-perpetuate within the environment they find themselves in [35,36]. The difference is not that some resources that they use may be produced half a world away and brought in by humans, since extraneous production of many resources is also true of island species relying on food washed in by the sea, e.g., [37]. Rather, the difference is that the source of the extraneous input is intentional human activity. In addition to traditional ecological inputs, human density is a strong predictor of urban biodiversity [38]. If humans are included in our concept of some ecological units, as is the case for agroecosystems [17,30], then urban environments should also be considered ecosystems—albeit, like those in agricultural settings, simplified ones.

3. Conservation Efforts Should Incorporate Urban Ecosystem Regeneration

The view presented above, as well as global agreements such as the Convention on Biological Diversity, reflect a societal commitment to the long-term survival of biodiversity. Conservation science has been focused on protecting biodiversity since its inception [39]. Like other human behaviors, engaging in conservation of biodiversity reflects a values-based, socially constructed choice [36]. "In wildness is the preservation of the world", wrote Henry David Thoreau [40], and wilderness has often been the focus of conservation efforts. But, what should the goals of conservation in an urban ecosystem be?

There is a growing realization that focusing on relatively "pristine" environments will not be sufficient to the magnitude of the task [13,41]. In response to this recognition, Rosenzweig [13] called for the establishment of a reconciliation ecology, aimed at constructing diversity-friendly spaces in human-dominated spaces. The incorporation of ecosystems created by human agency and that are different from historical reference states emerged as an option in restoration ecology circles in recent years and quickly became contentious [20,25]. Where supporters of UER pointed to the growing prevalence of areas so thoroughly human impacted that their return to a historical state would be impossible, detractors worried about the negative impacts of adopting this framework, including loss of support for more traditional conservation, enabling of species invasion, and more [42–44]. There is broad agreement that protection of an intact habitat, when possible, is the preferred option and that novel ecosystem (alternatively named "synthetic ecosystems"; ref. [45]) approaches should not be considered in pristine areas; extreme disturbance, such as urban construction, does not lend itself to either traditional conservation or restoration approaches; and in between these extreme cases, a mixture of benefits and harms (not necessarily being universally perceived as such by managers with differing views and goals) will follow from any of the array of tools available for addressing prioritized problems. The blend of human and non-human components has caused some authors to refer to them as "socioecosystems" [46], though the concept was not originally developed to describe urban ecosystems.

Dearborn and Kark [47] identified seven primary motivations underlying urban biodiversity conservation and lumped them into two major categories: naturalistic and anthropocentric arguments. To these, we add a few other potential motivations. Of course, these are not mutually exclusive, as the "one health" approach demonstrates, e.g., [48].

3.1. Naturalistic Arguments: Benefits to Non-Human Organisms

3.1.1. Protecting Local Biodiversity

Although much of the biodiversity found in urban areas is introduced, high urban species richness can also include native taxa (reviewed in [14,31,49]). Most attention is understandably devoted to native at-risk taxa, though those generally seem poorly served in urban settings [50,51]. For example, protected areas in the metropolitan area of Cape Town, South Africa, safeguard populations of the declining African penguin (*Spheniscus demersus*); [52]. Similarly, the San Joaquin kit fox (*Vulpes macrotis mutica*) is a highly endangered mammal found in Bakersfield, California, USA, where its adult density is higher than in natural habitats [53]. Urban areas can also protect native species, such as the Grey-headed Flying-fox (*Pteropus poliocephalus*) foraging in Melbourne, Australia, in ways that non-urban areas cannot afford to fund [54]. Moreover, even successful urban non-natives may be of conservation concern because of habitat declines within their native distribution range [55,56].

3.1.2. Creating More Continuous Opportunity for Native Species Movement

With fragmentation increasing rapidly, including as a result of urbanization, habitat connectivity has become an important topic in conservation [57]. Many urban areas are located near biodiversity-rich areas [58]. Thus, urban green spaces (UGSs) have the potential to serve as crucial stepping-stones for native taxa trying to shuttle between protected or less-degraded habitats or as additional stopping spaces during long-range migration. Connectivity among UGSs themselves is also of interest [57].

3.1.3. Understanding Environmental Change

Cities are already experiencing conditions, such as elevated temperature and CO_2 concentrations, that other locations will experience in the future [47]. The impacts are most keenly felt by some of the most economically disadvantaged individuals and in urban settings [26,59]. Thus, studying how organisms respond to them in urban settings today can provide information about what adjustments may be required to allow survival elsewhere in coming years. Additionally, studying the responses seen along urbanization gradients can give us information about the impacts of future urban expansion. Such studies can help mitigate future environmental impacts.

3.1.4. Convincing People to Protect Nature

UGSs also have educational value and exposure to them can help convince urbanites of the importance of conservation in non-urban settings [18,47]. For example, exposure to common species such as urban pigeons might be crucial to the later engagement of urbanites in the conservation of biodiversity elsewhere [60].

3.2. Anthropocentric Arguments: Benefits to Humans

3.2.1. Improving Human Well-Being

Gobster [41] argued that UER should "yield material benefits to people . . . while achieving ecological and environmental goals", including ways to address climate change. This is consistent with the "one health" concept, which calls for seeking win–win-win solutions that include environmental benefits with biodiversity ones (for an urban perspective see [48]). Certainly, time spent in natural settings is known to benefit human physical and mental health [61]. Moreover, some actions centered in urban areas, such as establishing community gardens, have the potential to provide substantial ecosystem service benefits ([62], and see below) and other benefits. Nonetheless, traditional restoration ecology is less interested in such everyday benefits to humans, leading Gobster [41] to call for "a broader range of values", including direct benefits to human residents, to be employed.

3.2.2. Providing Ecosystem Services

In its most strict interpretation, the term 'ecosystem services' refers to the benefits such as clean air and water that humans derive from ecosystems. In an early study from Stockholm, Sweden, urban ecosystem services were shown to offer substantial benefits to human wellbeing [63]. More recently, ref. [64] studied the value of ecosystem services in 25 urban areas in North America and East Asia and concluded that the magnitude of the benefits generally justifies the investment required to regain the ecological function via urban ecological infrastructure. And, in a recent review, ref. [65] showed that UGSs, particularly larger parks, act to cool urban spaces—an especially important service under likely climate change scenarios.

3.2.3. Fulfilling Ethical Responsibilities

Ethics have been a major justification for conservation since its inception [39], though the exact reasoning is still being discussed [66,67]. Thus, caring for urban wildlife can fulfill a desire to "do the right thing".

3.2.4. Other Reasons

Protecting biodiversity often has economic benefits to humans, for example, protection of African penguins in Cape Town, South Africa, brings in over USD $2 million in revenue per year [52], and higher home values correspond to increases in bird biodiversity in Lubbock, Texas, USA [68]. Similarly, "conservation gardening" has the potential to be a major source of income while improving urban native plant biodiversity [16].

4. Developing New Approaches for Conservation and Restoration in Degraded Urban Ecosystems

Traditional conservation efforts focus on maintaining existing biodiversity and ecosystem function in environments close to their original states (Figure 2, green circle, top left; McKinney, 2002 [4]). These are considered to be favored both because they are the result of evolutionary self-assembly processes and because they hold unique mixes of interacting species and abiotic settings (e.g., [69]). Thus, these efforts are 'backwards looking' (sensu [70]) because they look to past conditions as a measure of desirable future outcomes. Unfortunately, human activities often result in the degradation of such ecosystems (Figure 2, red circle, center bottom). The scale of the impact or other human activities may preclude natural recovery of the kind that is common following even extreme natural perturbations (e.g., [71]) and create environs inimical to many native species [47]. When timely natural recovery is unlikely, restoration ecology is often deployed with the goal of complete, or at least partial, reinstatement of pre-degradation states indicated by historical records or remaining reference sites [41]. Unfortunately, the lack of such reference sites and the extreme nature of the urbanization process make these preferred options impractical or impossible in many urban settings [13,23,24]).

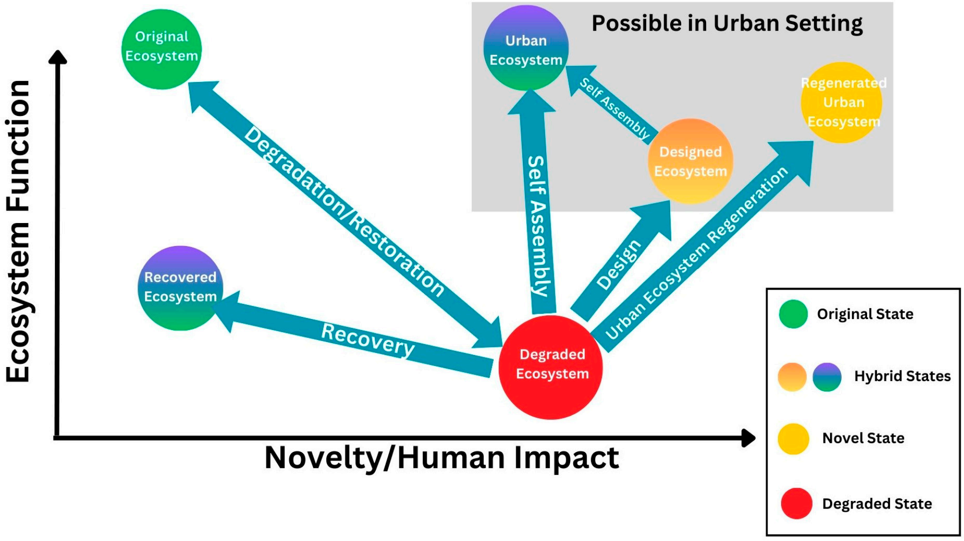

Figure 2. Possible pathways for recovery following human-caused degradation of an urban ecosystem. Outcomes range from a fully functional ecosystem very similar to the original (top left) to a highly functional ecosystem that is human constructed and mostly comprises non-native taxa (top right). Such outcomes are preferrable to the highly degraded state commonly encountered in urban settings (center, bottom).

Options for improving ecosystem function may be limited in an urban setting (Figure 2, grey box, top right). Since current conditions are so remote from the biotic conditions prevailing prior to urbanization, management options for achieving UER tend to be 'forward looking' (sensu [70]), based solely or primarily on perceived desired outcomes. Such 'novel' or 'synthetic' outcomes are consequently less desirable, from a conservation perspective, than the options discussed above. Although at least somewhat novel, urban projects help restore or provide some degree of ecosystem function. Although they may primarily rely on the species already found in the urban setting [41], some of which are non-native or even invasive, such efforts can provide conservation value. For example, existence of urban forest and wetlands habitats supports diverse avian faunas [49].

Managers have the option of designing fully novel or hybrid environments (Figure 2, yellow circles, top right). Nonetheless, a completely novel urban ecosystem may provide strong benefits related to climate change mitigation or improvement of human welfare, or even provide a habitat for endangered native species more affected by the ecosystem structure than by species identity, as is the case with urban peregrine falcons [72]. In addition to manager-initiated processes, sufficient time can allow natural recovery processes to occur, either from the originally degraded state, such as in an abandoned lot, or from a hybrid constructed one. These self-assembly processes can result in hybrid ecosystems comprises a mix of remnant native taxa and colonizing novel taxa (Figure 2, shaded green/purple, top middle), as often happens in roadways and abandoned lots [73]. Such mixes can also occur in the restoration of non-urban areas, such as the Great Basin in the U.S., that are undergoing significant alterations due to invasive species [74]. Because of the process involved (self-assembly) and the presence of native taxa, we consider such outcomes intermediate in their desirability. Novel/synthetic urban ecosystems also carry additional human benefits that make them preferrable to the degraded state of a fully urbanized environment, but also raise valid concerns [42–44]. The more novel and human-impacted environment is, in terms of species composition, the graver of the concerns (e.g., [36,42]), and, therefore, the lower the preference for such a management option.

5. Urban Ecosystem Regeneration and Its Implementation in the Face of Invasiveness and Other Problems

We use the term Urban Ecosystem Regeneration (UER) to indicate activities that increase or conserve biodiversity in urban ecosystems. In this framework, UER may cover a broad group of actions that share the broad goal of increasing biodiversity, especially of native species, within urban areas, though they may be disparate in methods. Under this framework, activities sometimes described as "Resilient Urban Design" and "Sustainable Urban Regeneration" (sensu [75,76], respectively) are included, as are "urban regeneration" projects (i.e., [77]), and even more comprehensive ecological restoration projects as described by the Society for Ecological Restoration [78]. The UER concept, therefore, applies to all human-directed actions intended to increase and/or conserve biodiversity within urban ecosystems.

Urbanization creates many opportunities, but also many challenges, to both humans and other species. Invasive species are often highly economically damaging [79] and cause significant ecological damages [80–82]. Therefore, one of the most important environmental issues, in our opinion, is the risk of UER facilitating biological invasion [4,14,25]) such as Mexican feather grass (*Nassella tenuissima*) by acting as a refuge for non-native taxa. A recent review [83] pointed out that invasion is the culmination of traits and events, many of them pertaining to the native range and evolutionary process of a species or population or to the transit process it must experience to arrive in its novel range. Like the domesticated organisms discussed by Göttert and Perry [84], those chosen and transported for restoration efforts avoid the initial stages discussed by Daly et al. [83]. Moreover, the UER process ensures that the next three invasion stages discussed by Daly et al. [83]—introduction, establishment, and proliferation—are actively, if unintentionally, supported by managers of UER that uses non-native species. This leaves only the final stage, spread, as unsupported by UER efforts, or by non-urban restoration that utilizes non-natives. Unfortunately, the very nature of the urban environment, where frequent transport of people and material occurs to areas near and far, greatly enhances the risk of further dispersal [84,85]. Moreover, urban environments can be the setting for further evolution of invasives once they arrive, making their potential impacts more severe [86]. This places a particularly strong precautionary principle onus on UER practitioners choosing non-native species, novel genetic lineages of species which are native, or even species native to the region but not the immediately surrounding ecosystem.

Invasive species have long been a concern in conservation (e.g., [44,67,87])—but seldom in the urban context. Of course, invasives are not only damaging in natural habitats, but also in cities and other human-modified systems. The same invasive birds that spread the seeds of non-native plants in Hawai'i's Volcanoes National Park [88] and the same house mice that negatively affect indigenous species in native habitats [89] also do so in urban areas, for example. The extensive discussion of the impacts of feral cats, which prey on both native and introduced species in both native and urban settings, is a good example of this (reviewed in [90]). These impacts should not be ignored as the control of invasives is considered.

Arguably, however, UER is only a minor contributor of taxa found in cities. Many urban species are natives [91], and the diversity of some native taxa may be higher in urban locations than in surrounding rural areas (reviewed in [14]). However, the ornamental plant industry, and to a lesser extent the pet industry, are major vectors for introduction in urban settings [92], as they are elsewhere [67]. Much greater attention is needed toward the unintended impacts of these commercial activities in both urban and non-urban settings.

6. Improving the Biodiversity and Other Contributions of Cities

All projections show that urbanization is going to continue, as will other land-use change. As it does, the risk of biological invasion by human-transported species will grow [85]. The question facing the conservation community is whether the current form of urbanization, which is typically blind to biodiversity impacts and often does little to mitigate likely climate change impacts for humans and other species, is what we would like to see, moving forward. We follow others in arguing that, since urbanization is part of the problem conservation science faces, it would ideally also be part of the solution (e.g., [13,19,45]). Below, we present some ways in which using the approach described above can enhance biodiversity while also addressing other concerns, consistent with the idea of win–win 'reconciliation ecology' espoused by Rosenzweig [13] and others.

The addition of domesticated species, particularly of plants, can mean that the species count in moderately urbanized areas is higher than in surrounding ecosystems [93]. Some authors have, mistakenly, in our view, interpreted that to mean that biodiversity has been 'enhanced.' Recently, Klaus and Kiehl [24] recommended "using established species-rich and well-functioning urban ecosystems as reference" when identifying a goal for UER. In their view, such models are already to be found "in many cities", with documented examples from Berlin, Germany [94] and elsewhere. Indeed, recent work such as the study of Fardell et al. [95] is helping identify the characteristics of urban yards that are more conducive to enhanced biodiversity in general, and that of native species in particular. Consistent with the emphasis of Klaus and Kiehl [24] to seek win–win situations, the results of such efforts certainly have the potential to provide many of the benefits to humans identified by Dearborn and Kark [47]. In that sense, UER outcomes are preferrable to the degraded states they might overlay (Figure 2). As rehabilitation of degraded sites proceeds, locations with little or no biodiversity value can be targeted for the addition of specific genetic varieties or taxa. However, a truly novel ecosystem comprising primarily highly tolerant widely distributed taxa is unlikely to provide many conservation benefits, though the ecosystem services provided may provide some global benefits. Thus, the conceptual framework of Klaus and Kiehl [24] depends on finding "species-rich and well-functioning urban ecosystems". Arguably, such urban design should also include incorporation of elements that reduce climate change, such as increased reliance on renewable energy as African cities develop [96] as well as greater attention to biological constituents. Whenever possible, we advocate the use of genetic stock from known local settings, perhaps helping offset losses in nearby sites.

Many UGSs, such as private gardens, primarily support non-native vegetation which can then spread outwards [97]. The nursery industry is a major source of non-native species [85,92], but could become a more biodiversity-friendly setting. Recently, Segar et al. [16] called for "conservation gardening" that uses "declining native plant species in public and private green spaces". For this to happen, supply limits and policy barriers would have to be addressed [16,85]. Presumably, this would require properly regulated release of appropriate genetic stock from conservation groups, such as botanical gardens, and its commercial propagation and marketing by the horticulture industry.

Making sure that urban green spaces provide as many benefits as possible requires not only cautionary measures such as reducing the impact of non-natives, but also actions that focus on biodiversity, especially where its enhancement overlaps with benefits to humans (e.g., [31]). For example, recent work shows that soil translocation can greatly improve the efficacy of biodiversity-restoration projects, particularly in some soils [98]. Such approaches can be adopted in urban projects, focusing on originating sites that are rich in native species and attractive to residents. As an added incentive, native vegetation is less likely to require supplemental watering, a strong incentive in a world where almost a billion urbanites are already water limited, a number expected to double by 2050 [99]. Citizen science, touted as effective in addressing invasion in natural habitats [100], offers an avenue for harnessing the interest of urban residents and getting them better engaged in exurban conservation issues as well (e.g., [101]).

Given ongoing declines in many insect species, particularly pollinators such as butterflies [102], UER has the potential for positive impacts that extend far beyond plant diversity. Modifying lighting regimes and technologies near UGSs can further help insect populations [103]. By offering UGSs, university campuses [104] and cemeteries [105] could play important roles in urban conservation, although management of both rarely prioritizes the enhancement of biodiversity. Further, adapting structures such as roofs and walls into green roofs and walls can create habitat analogues [106], thereby enhancing their suitability for multiple species [107]. Finally, ambitious urban areas can afford investments that would be impractical in native habitats, such as installing a dedicated cooling sprinkler system like the one which occurred in support of flying foxes in Melbourne, Australia [54]. Such initiatives may become more essential as climate change exacerbates heat stress on vulnerable populations.

There is another way in which urbanization contributes to biodiversity conservation: though it affects the biodiversity potential of the urban space [38], housing people in dense cities frees up better-protected habitats elsewhere (e.g., [108]). Moreover, UER-focused design of future urbanization, particularly in rapidly urbanizing regions such as Africa, the U.S. Southwest, and elsewhere, can help create environments that are not only endowed with better UGSs but are also more energy efficient [109].

7. Conclusions

At the core of modern conservation is the principle of "no net loss" of habitat or species [69], p. xxvi. Restoration was initially rejected as a tool for achieving that goal for fear that it might encourage destruction of habitats under the misconception that they can later be recreated [110,111]. Similar arguments have been made for rejecting the "novel ecosystem" concept, and by extension UER: detractors worry, perhaps with some justification, that adopting it and investing in conservation in such locales will come at the expense of traditional conservation efforts, priorities, and sites [36]. In the meantime, adopters find the approach well-suited for describing urban settings, among others.

It appears increasingly unlikely that society will limit gas emissions to bound global climate change to the 1.5 °C deemed essential to maintaining the current ecosystem functions and human well-being [9,26,70,108]. Three decades ago, Noss and Cooperrider [69], p. xix noted that changes in our understanding of the world and in the state of the world mean that "conservation policy is never static, but always evolving". Such a change in understanding involves developing knowledge of the impacts of global climate change, which means that habitats that now seem fine, such as some forest stands in California, USA, are already doomed "zombie forests" [112]. Given the rapid change in our world, now experiencing what is increasingly called the Anthropocene [113] and dominated by humans and their livestock [10], "novel ecosystems might become the new normal" everywhere [21]. Even as conservation of natural habitats increases in importance, the potential contributions of biodiversity conservation within cities also grow [14]. We, therefore, argue that making use of extensively human-altered lands such as UGSs for conservation allows badly degraded lands to support conservation goals. Ultimately, what matters is that urban ecosystems are a necessary component of such conservation efforts [14,21]), rather than whether they are called "novel ecosystems" [22], "Synthetic ecosystems" [45], UER, or something else.

Self-sustaining urban populations of plant and animal species not only have value in the present, but also offer potential for future self-assembly and evolutionary processes [73,114]. Thus, the findings of Wright et al. [115] that UER using common species may be especially methodologically easy and likely to succeed appears to offer a promising direction. Biodiversity-minded urban design can enhance urban biodiversity [38,81,116] and improve the physical and emotional wellbeing of human residents, simultaneously achieving multiple desirable outcomes. Tools such as green roofs and a focus on native plantscapes should, therefore, be viewed as investments rather than expenses [85,97].

Two decades ago, Miller and Hobbs [18] said "Now is the time for conservation biologists to work with the public to design a better future through development that minimizes adverse effects on native habitats and open-space protection that achieves conservation goals". We believe that call is even more pertinent today. "Wilderness" conservation, epitomized by the famous "wildness" quote from Thoreau [40], has been the traditional focus of conservation. However, given the ever-growing percentage of the planet taken up by urban and other human-constructed ecosystems, we now require a more flexible mindset. Perhaps another quote from Thoreau, written in his diary in 1859, has greater potential to enhance future biodiversity protection while improving human wellbeing: "Each town should have a park, or rather a primitive forest . . . a common possession forever, for instruction and recreation".

The Anthropocene, and particularly global climate change, creates an unprecedented risk landscape. An analysis released by [26] makes it clear that severe impacts are likely and that current policy choices will be insufficient to avoid them. Perhaps with that scenario in mind, the National Academies of Sciences, Engineering, and Medicine [117] has called for cautious exploration of solar geoengineering, not as a substitute for reducing greenhouse gas emissions but as a potential approach for reducing impacts, despite the obvious risks of such an approach. More recently, the United Nations Environmental Programme [118] acknowledged that an "operational [Solar Radiation Modification] deployment would introduce new risks to people and ecosystems" and that it "is not a substitute for mitigation". Despite arguing that "deployment is not warranted at present", it nonetheless calls for "a globally inclusive conversation on" solar geoengineering [118]. UER also carries risks, albeit far less severe in scale and scope than those of geoengineering, particularly in the context of biological invasion, nor is it a suitable replacement for aggressively reducing the loss of biodiversity, wherever it may be occurring. However, in very much the same way as these authors [45,117,118], we recommend the cautious and deliberative process of incorporating it into our conservation toolkit, while striving to identify and avoid negative side effects.

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