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Review

Different Jargon, Same Goals: Collaborations between Landscape Architects and Ecologists to Maximize Biodiversity in Urban Lawn Conversions

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Abstract: Landscape architects and ecologists alike are embracing the opportunities urban areas present for restoring biodiversity. Despite sharing this goal, their efforts are rarely coordinated. For landscape architects, aesthetics and programming are at the forefront of design and must be given substantial attention, while ecologists look to scientific research to guide their decision-making. However, the lack of scientific research aimed at developing best ecological practices for native landscaping—particularly at small urban scales—make this difficult at a time when many residents are converting their lawns to more sustainable landscapes ("lawn conversions"). We survey literature from the fields of design and ecology to synthesize relevant information about small-scale urban landscaping projects and to identify instances in which practitioners from both fields are already "speaking the same language," only with slightly different vocabulary. To further promote transdisciplinary collaborations, we present a new glossary tool to highlight these parallel concepts across fields. We discuss specific situations in which design priorities can be aligned with ecological function and propose that more attention should be placed on traditional principles of garden design, including perception, complexity and repetition, rhythm and order, proportion and scale, and form and structure. Finally, we argue that each new urban lawn conversion presents an opportunity to test ecological theory at the site-scale, conduct much-needed research on the impacts of design principles on habitat potential, and promote a collaborative urban ecological design aesthetic.

Keywords: urban landscape transformation; constructed ecologies; lawn conversions; urban ecological design; transdisciplinary collaboration

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1. Introduction

Urban, suburban, and exurban expansion are the primary reasons for habitat fragmentation and loss in the United States [1,2]. As land is increasingly converted to development, turfgrass has surpassed corn in total acreage to become the most common crop in the country, comprising approximately 40,000,000 acres [3–5]. Lawns, with their associated maintenance, fertilization, and water needs, pose an environmental threat to wildlife habitat and biodiversity [6–8]. There is a clear need for intervention to increase wildlife habitat within these contexts, but effective strategies for accomplishing this are less clear.

The role of landscape architecture in influencing aesthetics and homeowner behavior is crucial to the adoption and success of alternatives to traditional lawns. Fortunately, particularly in drought-affected areas, the public is increasingly embracing the idea of converting lawns in urban and suburban areas to low-water native plants as a means of habitat restoration and water conservation [9]. Financial incentive programs offering rebates for lawn conversions have additionally been effective at encouraging urban dwellers to remove lawns [10]. In a 2020 Washington Post article, Home & Garden columnist Adrian Higgins wrote that "gardening for pollinators and other desired wildlife is in vogue" [11]. Better marketing techniques and improved nursery availability, as well as greater public awareness, have increased demand for native plants in particular [12]. According to the most recent Residential Landscape Architecture Trends Survey conducted by the American Society of Landscape Architects (ASLA), the project type with the highest consumer demand in 2018 was native plants (88.3%) [13]. As this trend increases and homeowners continue to strive towards the suburban ideal of an "ecology of prestige" [14] by replicating garden designs and features within their neighborhoods, then the potential exists to generate a neighborhood level conservation ethos through friendly neighborhood competition for wildlife habitat [15].

At the same time that landscape architects have embraced native plants in their urban projects, ecologists are increasingly turning their attention to the built environment and other constructed ecologies as valuable areas to restore and protect biodiversity [16]. Indeed, cities are becoming important refugia for certain wildlife populations of pollinators [17], including birds [18], butterflies [19], native bees [20], and dragonflies [21]. Both exotic and native plants have been shown to host many important wildlife species within urban areas [22]. A number of non-profit organizations (e.g., Xerces Society, Audubon Society, Native Plant Societies, etc.) have been advocating for incorporating more native species into urban landscapes for their benefits for wildlife and environmental sustainability. State and regional organizations have also joined in native plant promotion and integration efforts. For example, the California Native Plant Society (CNPS) recently launched a USDA-funded campaign called "Bloom! California" aimed at increasing the residential and commercial use of California native plants by promoting them as "the norm not the exception" [23].

Higher levels of education are the most consistent predictors for concern about the environment [24], suggesting that educational campaigns, interpretive signage, and public discourse lead to greater neighborhood-level adoption of native plant gardens. However, traditional educational methods that rely primarily on information disseminated through lectures and printed material typically fail to spur behavioral changes or elicit desired environmental responses [25,26]. A more effective predictor of environmental behavior is the role social norms play in guiding actions and decisions [27]. Social contagion is the spread of behaviors, attitudes, and aesthetics through groups. Zrnyslony & Gagnon [28] found that residential landscape designs and management practices are an example of social contagion and that residents are directly influenced by the shape, color and location of their neighbors' gardens.

Aesthetic preferences continue to form the basis of most landscaping decisions by homeowners—more than environmental or wildlife habitat goals [29,30]—and aesthetic experience ultimately drives landscape change [31]. When restoring habitat in urban contexts, design principles are at the forefront and must also be given substantial attention. Here, we hope to advance an effort to optimize the goals of ecologists and landscape architects to build urban landscapes with aesthetic, social and ecological benefits.

This paper focuses on how small-scale urban landscaping projects, such as lawn conversions and other habitat design interventions, may be best designed to support native biodiversity in addition to meeting the aesthetic and social needs of urban-dwelling human populations. Specifically, we ask—which landscape design principles align best with established ecological principles for maximizing biodiversity in urban areas? What are the tradeoffs and synergies between ecological, social and aesthetic benefits? How do traditional planting design principles, such as perception, complexity and repetition, rhythm and order, proportion and scale, and form and structure, modulate benefits provided by native plantings in urban spaces, and how can landscape architects and ecologists work together to maximize these benefits?

We discuss specific situations in which established design methods and theories can and should be leveraged to maximize ecological function. We propose synthesizing relevant information from the fields of ecology and design to optimize habitat impact in urban areas and posit that more attention should be placed on garden design principles for neighborhood-scale urban restoration projects. We argue that "calls for collaboration" should not rest entirely on designers to adopt the universal theories and quantitative assessments of ecological science [32], but that ecologists must similarly consider the human dimensions of constructed ecologies [33].

The terms currently used to describe the process of restoring biodiversity in urban contexts (Table 1) are loosely defined, broadly interpreted, and often overlapping, making it difficult for academics and practitioners in both fields to agree on any single term to adopt. For the purposes of this paper, we use the term "lawn conversion" to apply to any small-scale urban garden or landscape project. We define a lawn conversion as the process of replacing existing turfgrass with drought-tolerant (primarily native) plants to reduce water use and improve wildlife habitat.

Table 1. Terms used to describe urban biodiversity.

Lawn Conversion	Backyard Restoration
Pollinator Garden	Habitat Garden
Xeriscape	Drought-Tolerant Garden
Waterwise Garden	Sustainable Garden
Natural Garden	Native Garden

Collaborative work is often characterized by the problem of using different terms to explain the same thing. To further explore this concept of "different jargon, same goals," we present a comparative glossary (Appendix A) of landscape architecture and ecology terms. We believe that, in addition to providing a useful starting point for any landscape architect/ecologist collaboration, this working glossary can be used more generally to facilitate a broader understanding of the beliefs and theories underpinning the two fields.

Finally, we argue that every lawn conversion presents an opportunity to test ecological theory at the site-scale, conduct much-needed research on the impacts of design principles on habitat potential, and promote a design aesthetic that integrates ecological theory with the principles of design.

2. Materials and Methods

We surveyed the ecological and landscape design literature with the goal of consolidating information from these typically disparate fields in order to provide a basis for collaboration between them and to develop best practices for urban landscaping projects. We were interested in comparing concepts and relationships from the fields to provide an understanding of overlapping theories relevant to both disciplines.

We drew from the literature on urban design, landscape architecture, and urban ecology, when possible, but also from the substantially larger wildland restoration literature to support our conclusions. The initial identification of scientific literature was conducted from November to December 2020 by searching for articles using the Scopus, Web of Science, and Science Direct platforms, in addition to articles previously known to the authors. We also searched Google Scholar to capture relevant articles that may not be included in Web of Science Previews or BIOSIS Previews

We focused initially on data from both empirical and conceptual studies being referenced by academics in landscape architecture, urban ecology, conservation biology, and restoration ecology. We subsequently broadened the search to include books and popular press articles to ensure that applied theories and practices from scholars and practitioners across both fields were also represented. Key steps in the process included synthesizing relevant concepts and terms within the literature, specifically similarities between theoretical concepts and terminology within the disciplines of design and ecology. A search strategy was developed to identify the relevant literature by adopting a broad range of keywords across academic fields. Prior to starting our search, we created a list of keywords that, based on our respective disciplinary expertise, we knew to be commonly used in either design or ecological literature (Table 2). For each keyword, we tested similar terms to ensure that the keywords we selected were effective and produced relevant results.

Table 2. Key concepts and terms in design and ecology.

Design Keywords	Ecology Keywords
Aesthetic	Biodiversity
Authenticity	Biofilters
Citizen Science	Carbon sequestration
Designer ecology	Colonization
Display	Corridors
Garden	Dispersal
Gentrification	Erosion
Health	Facilitation
Housing developments	Habitat Generalists
Landscape urbanism	Habitat Specialists
Pattern	Indicator
Preference	Matrix
Property value	Metapopulation
Psychological	Monitoring
Spatial	Pollinator
Swath	Remediation
Tactical	Restoration
Texture	Soil
Urban	Species
Landscaping	Survival
Urban	Water storage
Xeriscaping	

We developed a filtering process for each paper (article, book chapter, etc.) in our search results to compile a list for final review. First, we read each title and filtered out irrelevant citations (e.g., papers not related to urban ecology or landscape design). Next, we read the abstracts of each study, excluding papers that did not relate to native habitat within cities. Finally, from this narrowed set of results, we identified papers specifically related to the design of small-scale urban habitat interventions. Our survey yielded 268 papers, book chapters, and articles on topics ranging from naturalistic planting design to island biogeography theory.

The relevant studies were then reviewed in full. Each paper was included only if it directly or indirectly addressed the following question: 'how do design elements modulate benefits provided by native plantings in urban spaces?' Our final list consisted of 124 total papers. Finally, we identified five more specific questions spanning both the ecological and design literature. These questions include:

1. What are the Effects of Native vs. Exotic Plants on Urban Dwellers?
2. Does the Number and Identity of Native Plants Matter?
3. Does the Arrangement of Plants in Small-Scale Urban Plantings Matter?
4. Does Size and Distribution of an Urban Planting Matter?
5. How Does Biodiversity Interact with Human Health and Well-Being?

We organized our results and discussion to address these five questions, aligning landscape design principles with established ecological theories to provide a multi-disciplinary approach to lawn conversions and other small-scale native plantings.

A secondary goal was to link terminology between ecology and landscape architecture in order to increase opportunities for interdisciplinary communication and collaboration. This approach helps identify instances in which practitioners from both fields are "speaking the same language" but using slightly different vocabulary. In order to achieve this, selected papers were divided into two interconnected themes: (i) Landscape Design Theory and (ii) Ecological Restoration Theory. They were then examined for intersectional concepts and terminology related to urban ecological design. We then identified parallel terminology within each theme in order to create a glossary of terms that could serve as a usable tool within both disciplines.

3. Results and Discussion

Our survey of the relevant literature highlighted similarities across disciplines in both theoretical and applied design approaches to lawn conversions. Using our research questions as guides, we paired traditional design principles with established ecological theories to establish five interconnected themes: (i) Perception—Effects of Native Plants on Urban Dwellers; (ii) Complexity and Order—Numbers and Species of Plants to Include in Urban Designs; (iii) Repetition and Rhythm—Arrangement of Plants in Small-Scale Urban Plantings; (iv) Proportion and Scale—Lawn Conversion Size and Urban Distribution; and (v) Form and Structure—Plant Biodiversity and Human Health and Well-Being. The subsequent sections discuss these five themes, interpreting overlapping ideas and providing implications for future scholarship and applied practice.

3.1. Perception—Effects of Native Plants on Urban Dwellers

There is an ongoing debate among factions of landscape architects and, to a lesser extent, ecologists, on the role of exotic vegetation within managed landscapes [34]. One side argues that, in the face of climate change, a plant's adaptability and the ecosystem services they provide are more important than their geographic place of origin (for example, [35–37] The other side argues that a massive loss of biodiversity is underway due to the effects of climate change, biological invasion, and human disturbance and that the introduction of exotic vegetation (including lawns) further contributes to the losses [38–41]. Both exotic and native plants have been shown to host many important wildlife species [42]. For example, Hostetler and McIntyre (2001) [43] compared residential yards with xeric landscaping to those with turf grass in the U.S. Southwest and found more diverse bee communities within the xeric landscapes, particularly in the later months of summer. Blackmore et al., (2014) [44] found that benefits to urban bees and pollination services could be substantial simply by converting small plots of mowed turfgrass to flower-rich landscapes. Many nonnative exotic species have been shown to host to native insects– for example, Graves and Shapiro [45] found that eighty-two of California's 236 butterfly species utilize nonnative plants for ovipositing or feeding.

However, while there are many drought-tolerant exotic species that perform well in urban gardens (for example, Spanish lavender in a California garden), these nonnative species do not necessarily fulfill all of the same ecological roles as native species. One concern is that nonnative species do not support specialist insect herbivores that co-evolved with these species, such as monarchs, pipevine swallowtail, etc., as well as species of terrestrial birds that rear their young on insects [46,47]. Another is that nonnative species may not bloom at the right time of year or not have the same nutritional value as their native counterparts. For example, a recent study found that the reproduction and survival of Carolina chickadees in residential yards were negatively impacted by the abundance of nonnative plants. This study found that populations of this species were only maintained when nonnative species made up <30% of plant biomass [48]. In addition, many native plants are known for supporting specific species of native bees [49].

In many parts of the world, frequent and prolonged drought has increased public understanding of water conservation strategies, leading to greater levels of acceptance of lawn conversions and low-water residential design [3,50]. Low-water landscapes are not necessarily composed of native plant species—in fact, the majority of low-water and drought-tolerant species available in commercial nurseries are nonnative exotics (pers. obs.). However, despite the greater availability of drought-tolerant exotics, there is a growing preference amongst customers and landscape architects for selecting species that are native to the region in which they are being used [51]. This is primarily based on an appreciation for regionally identifiable landscapes [12], along with the tradition in landscape architecture to include a 'sense of place' in the natural and cultural landscape conservation process [52]. Increasingly, landscape architects are looking to embody this concept of authenticity through the creation of native plant gardens, leading homeowners to increase the prevalence of native plants within their yards. Better marketing techniques and improved nursery availability, as well as greater public awareness, have also increased demand for native plants [12].

At the individual plant level, interest in native plants increases as a result of public education on their benefits [53,54]. Educational campaigns linking specialist insect herbivores with their host plants (e.g., monarchs and milkweeds; pipevine swallowtail butterflies and pipevines) have been especially successful at promoting specific native plants and inducing homeowners to add them to their gardens. Similarly, the inclusion of culturally significant native plants into individual residential landscape designs may ultimately encourage more widespread adoption. "Passalong" plants are plants (often native) shared between friends and family across generations and may be common within neighborhoods, but aren't marketed or sold commercially in large numbers [55]. The plant's repeated use within a neighborhood can function as a strong identifier of place and as an act of community making and belonging [56].

3.2. Complexity and Order—Numbers and Species of Plants to Include in Urban Designs

In the field of restoration ecology, the goal is often to increase plant biodiversity by including many native species, as well as to 'bet hedge' in case some do not thrive in abiotic conditions of the restoration project. This strategy is based on the ecological concept of niche theory as it is applied to plant communities (ex. Turnbull et al., 2016) [57], which suggests that more diverse plant assemblages may support higher biodiversity of other taxa– more plant species create more ecological niches, which can then be occupied by a higher number of pollinator, bird, and mammal species that interact with these plants and with one another. This has been shown in a variety of taxa within urban environments: Crist et al., (2006) [58] found a positive relationship between edge extent and plant richness on generalist predator and parasitoid species, and both plant species diversity and morphological diversity (foraging height) has been linked to urban bird conservation [59,60].

Similarly, in landscape architecture, the increasingly popular aesthetic of the New Perennial Movement prioritizes high biodiversity within native gardens. This movement is based on the concept of "visual ecology"—using forms, colors, and textures that reflect the way plants arrange themselves in natural plant communities to help mimic the emotional responses that humans get when immersed in nature [61]. Such ecologic aesthetics strive to fully engage with the deep human response to nature, but to do so at an intimate, human scale, using a large diversity of plants (often native) woven together in structured and ordered ways to create a sense of "organized wildness." In addition to aesthetic benefits, the social and educational benefits of species-rich plantings are well established. For example, more species-rich plantings have been linked to higher psychological benefits than less species-rich plantings [62–64].

However, it is also important to recognize the tradeoffs of maximizing biodiversity within small patches. Biodiverse plantings may provide a variety of habitat types at the local scale but not provide contiguous habitat required to support mobile or large taxa. Prioritizing a single habitat type across many patches may make a larger positive impact at the regional scale [65]. For example, if the goal is to increase habitat for the endangered monarch butterfly, it might be better to have a network of habitat gardens with high densities of the host plant, milkweed, than to have each garden have a single milkweed plant.

Finally, because lawn conversions require human intervention and maintenance, and each native species is adapted to a unique set of abiotic conditions, it may be difficult to maintain the abiotic conditions for a large suite of species; i.e., more species may be more difficult to take care of than fewer species. Given the aesthetic importance of plant health, it is important to consider the amount of time required for maintaining a biodiverse native garden.

Because the public has an aesthetic preference for a hybridized mix of exotics and native species [66], one solution to the question of how many native species is enough is to adopt a step-wise approach to incorporating native plants, starting with species that may be more familiar to people and slowly adding wilder looking ones as sustainable design becomes more socially accepted and cultural paradigms begin to shift [67].

3.3. Repetition and Rhythm—Arrangement of Plants in Small-Scale Urban Plantings

Ecological research has focused on the natural spatial organization of plant communities, and how this organization can modulate ecosystem services in the wild. Groups of plants can naturally spread themselves out in spatially interspersed mixes throughout a space, or clump together in a spatially segregated mosaic of single-species "patches." When restoring native wildland ecosystems, ecologists aim to mimic the natural spatial patterns found in the landscape.

Evidence in the literature shows that landscapes comprising patches of single-species plants within a broader matrix provide ecological benefits. We found that plant density within a given patch can have effects on abiotic factors such as erosion, bioremeditation and water quality [68–71], as well as plant facilitation and survival [72,73]. In general, more clumped plantings lead to higher plant facilitation and survival, but in arid environments, dense plantings may lead to interspecific competition and depletion of resources [72]. Similarly, higher planting density can reduce the deep soil moisture available for shallow-rooted shrubs [73] and trees [74,75]. Therefore, clumped planting may make more sense for non-woody species and in less arid environments or where supplemental water is provided.

Within urban landscapes, multiple factors including plant density, patch size, and spatial arrangement contribute to the garden's ability to attract wildlife. For pollinators, optimal foraging theory predicts that foraging animals will prefer to target patches of plants with high, consistent levels of food, which can be enhanced at higher densities. This means that the density of plants within a given area may often be more important than the size of the patch itself. For example, studies show that for the perennial wildflower button wrinklewort (*Rutidosis leptorrynchoides*), the density of plants, rather than the size of the patch, mattered for the number of pollinators that visited [76,77]. However, Bauerfind et al. (2009) found that plant density and patch size mattered equally to attract the threatened violet copper butterfly (*Lycaena helle*) to its host plant, bistort (Polygonum bistorta) [78]. A recent study published in 2019 found that monarch eggs and larvae were significantly more abundant (2.5–4 times more) in gardens where milkweeds were spaced in a border around the perimeter of a garden rather than interspersed amongst other flowering plants [79]. This suggests that spatial arrangement within a garden plot, especially for targeted host species, can also make large impacts for specialist pollinators.

Landscape architects must also make decisions about the arrangement of plants within a lawn conversion, but they are less constrained by the natural arrangements found in wildlands and more driven by aesthetics. For example, once a given number of species has been selected for the plant palette, should these species be clumped together (spatially segregated) or spread out (spatially interspersed) throughout the design? Should the plantings be dense (many individuals per species) or sparse (fewer individuals, separated by hardscaping or mulch?).

Since native plantings are often seen as 'messy' when they are introduced into residential landscapes [80], one compromise is to plant a diverse, heterogenous mosaic composed of groups of plants of the same species. Landscape architects refer to these single-species patches as swaths or drifts, based on traditional horticultural aesthetics that favor massing colors and species together rather than interspersing them. Nassauer (1992) [81] argues that the way to culturally normalize ecologically functioning landscapes is to design and describe them using conventional landscape forms and terms. Native plantings are more likely to be considered attractive if they are utilized within traditional design contexts—i.e., they do not contain gaps of bare soil between the vegetation, are kept in orderly borders, and look neat and well cared for [82,83]. This concept of 'messy ecosystems, neat frames' plays a role in making native plants more aesthetically palatable; including 'cues to care' within a landscape design provides a means of adapting cultural expectations to recognize new landscape forms that include greater biodiversity [84].

3.4. Proportion and Scale—Urban Planting Size and Urban Distribution

The tradeoffs between concentrating native plants into larger centralized urban gardens or dispersing them across many smaller gardens is reminiscent of the Single Large or Several Small (SLOSS) [85] debate. This ecological debate, born out of Island Biogeography theory, applies these principles to the design of wildlife reserves. It asks whether a single large reserve or several small, non-isolated reserves is preferable for maximizing the conservation of diversity, target species, and/or abiotic ecosystem services. The value of lawn conversion projects, and how this might change with scale and structure, is still not known, but could have important implications for restoration efforts in the context of residential-scale plantings, along with other design principles such as spatial arrangement and species selection. For example, Roux et al., (2015) [86] did a SLOSS analysis of urban trees in modified landscapes, considering the aboveground biomass of the urban tree the size of the patch. The authors found that several small and medium trees supported an equivalent number of individual birds and bird species as a single large tree [86].

There is some evidence that suggests abiotic ecosystem functions associated with urban restoration can be scale-dependent, and may increase with patch size. Larger patches may support greater abiotic ecosystem functioning, particularly related to soil carbon sequestration and nutrient cycling (but not necessarily stormwater storage—see Snodgrass et al., 2000) [87]. However, numerous smaller fragments can also encompass broader environmental variation, due to being located in disparate areas. This diversity in abiotic conditions means more niches for specialist species and potentially more local adaptation—and genetic diversity—by species.

In general, the importance of small versus large native plant gardens in an urban context depends most strongly on the focal taxa [22], their life histories, and in particular, whether these species are specialists or generalists of particular plant species. For example, Soga et al., (2012) [88] found that carabid beetles were particularly sensitive to edge effects in urban forest remnants, so that larger patches were able to support greater carabid beetle richness because of their lower edge to area ratio. Contrastingly, Crist et al. 2006 [89] found that smaller patches with more edge habitat supported more parasitoid insect species. Blaauw and Isaacs (2014) [89] investigated the effect of wildflower patch size on pollinator species and found that patch size had little effect on more generalist species like honeybees and hoverflies, but had a positive effect on wild bees. For birds, Huste and Boulinier (2007) [90] found that local rates of extinction and turnover were related to urban habitat patch size for migratory species, but not for sedentary species. A study in Chicago showed that ecological practices in groups of neighboring yards was more important, in the aggregate, for native bird species richness than at the individual yard scale [91]. Together, these studies suggest that larger native gardens may be beneficial for biodiversity because they generally support specialist species and migratory species, but that smaller gardens may be sufficient to support more generalist species, species that benefit from edge effects, and may encompass more species due to variation in abiotic factors.

Recognition of the value of urban ecology and with it, the importance of lawn conversions, has elevated landscape architects to leadership roles in city planning, providing them with greater opportunities to collaborate with urban planners and influence the distribution of native plants beyond the local garden scale, including city parks, transportation corridors, and master planned communities. Landscape architects are also regularly being contracted by local governments to administer residential incentive programs allocating resources for water conservation programs, such as lawn rebates. As landscape architects take the lead in large, multi-stakeholder and interdisciplinary projects, they are increasingly being called on to consider the ecological impacts of design at the scales of neighborhoods or even whole cities. For example, a landscape architect might need to decide where to include gardens within a newly planned neighborhood and to consider the resulting trade-offs in both native biodiversity and aesthetic/social benefits from mass-planting native plants in the largest greenspaces versus small-scale plantings in individual yards (i.e., planting 100 native plants in a shared urban landscape vs. planting 10 native plants in each of 10 urban backyards).

From a landscape architecture perspective, there are also tradeoffs between larger and smaller urban native gardens in aesthetics and cultural acceptance. Larger patches of native plants are more visible as ecological interventions and can be used to create an appealing aesthetic that visually contrasts the built and natural landscape [92]. Similarly, large gardens designed to be visually dramatic at some point in the growing season can demonstrate the "ecological worthiness" of native vegetation and help make native plantings acceptable at the residential scale [67]. Aesthetic experiences with the landscape are an effective way to engage people with ecosystems and promote beneficial ecological change [31]. The more detailed and engaged our ecological knowledge is of a space, the more sophisticated our understanding of its aesthetic characteristics [54,93]. Thus, the inclusion of large swaths of native plants can be an effective way to incorporate ecological storytelling and education into landscape design. Finally, the larger scale is also more likely to trigger neighbor mimicry, in which residents make their own landscaping decisions based on the landscaping of their neighbors [47,49]. Peterson et al. (2012) [94] found that in neighborhoods with large areas of native plant gardens, preferences for conventional turf grass landscaping were replaced by preferences for designs including native plant gardens.

Recent studies of homeowner preferences for front yard designs corroborate these theories. Hitchmough (2008) [67] emphasizes the importance of immediate aesthetic appeal to people who may not have awareness about native plants. These people might be better drawn in by a mix of familiar exotic species and natives. Similarly, Meyer (2008) [66] suggests a hybridized approach to create landscapes that function ecologically and perform socially and culturally. Hayden et al., (2015) [30] found that aesthetic preference takes precedence over other criteria, such as water use and other best management practices, and that homeowners typically prefer a conventionally landscaped home that has been retrofitted to incorporate a small number of native plants and other water conservation features over one primarily featuring low impact, native landscaping. This suggests that several 'micro' restorations, which more subtly incorporate natives into landscapes, may have high aesthetic value.

3.5. Form and Structure—Plant Biodiversity and Human Health and Well-Being

The benefits of time spent in nature, notably the reduction in stress, anxiety, and depression, are extensive and well documented [95–97]. The psychological benefits of greenery have been shown to depend on how immersed an individual is within a landscape [98] and how species-rich the plantings are [63]. Fuller (2007) [62] found that the psychological benefits gained by park users increase with levels of species richness. Methorst et al., (2021) [99] determined that plant and bird species richness are positively related to mental health. Other research posits that the proximity of a green space to an individuals' living environment (rather than just one's general neighborhood) is the best predictor of health benefits [100,101]. Residents in dense urban areas report higher levels of poor health than those with more proximal greenspace [102]. Maas et al., (2006) [103] found a 5.3% difference in self-reported health between residents who lived in a home 90% surrounded by greenspace vs. 10%.

Residential gardens, which tend to be spread out more evenly throughout urban areas, may offer a subset of the health benefits that larger parks and greenspaces provide. The act of gardening has been shown to reduce levels of stress, as measured by salivary cortisol levels and self-reported mood [104]. Zhang et al., (2021) [105] describe home gardens as "ecological medicine" with healing functions to improve mental health and ecological functions to enhance urban biodiversity. These "micro-greenspaces" can provide needed connections to nature for residents in urban areas [106–109]. For example, Kardan et al., (2015) [110] found an increase in health perception with every extra ten trees in a city block. Similarly, a view out a window or a single potted plant has been shown to improve mental health and well-being [111]. However, to make a genuine impact on human well-being, merely ensuring the provision of greenspace is not enough; urban gardens also require biodiversity and ecosystem functioning [112].

It can be particularly challenging for residents in low-income urban residential neighborhoods to interact with nature due to the lack of proximal parks and open spaces [108]. Expulsive zoning practices have played a significant role in exploiting minority residential communities for commercial and manufacturing interests, prioritizing industrial development over community greenspace design [113]. Residential greening, the incorporation of features such as green alleys, urban street canopy, and drought-tolerant/native plant gardens, within a community, can enhance cohesion of a neighborhood without altering the dominant culture of the neighborhood [114]. Recent studies have shown, however, that the combined strategies of environmental clean-up, land restoration, and green amenity creation tend to be targeted to white and socially and economically privileged residents and tourists at the expense of existing residents [115–117]. This can lead to the displacement of the urban poor under the guise of sustainability and green planning [118]. One response to the gentrification of urban areas resulting from urban greening orthodoxy is the concept of "just green enough." The idea, which lends support to the microscale approach of adding individual native plants to multiple lawn conversions, promotes integrating urban greening at a "small-scale and in scattered sites" instead of in larger, more conspicuous green spaces [119,120].

4. Conclusions

Our goal was to synthesize relevant information from the fields of ecology and design to determine what we can currently infer about small-scale native plantings such as lawn conversions in urban areas and to instruct as to where further research is needed. This multidisciplinary approach also allows us to identify instances in which practitioners from both fields are "speaking the same language" with slightly different vocabulary. An example of this synergy is the common finding in ecological and landscape architectural studies that diverse mosaics of single-species patches are both ecologically and aesthetically valuable. These single-species patches (as opposed to homogenous landscapes made of intermixed species) seem to have more benefits for insect foragers and also for plant pollination, which is in line with ecological concepts of optimal foraging theory. Landscape architects similarly see the benefits of planting in larger, more organized swaths of individual plants rather than over dispersed patches for aesthetic purposes ("Repetition & Rhythm" design principle).

When restoring in urban contexts, aesthetic and cultural benefits are at the forefront and must also be given substantial attention. We argue that the goals of ecologists and landscape architects are not at odds with one another, and that in both fields, the function of an urban habitat should be defined not only by the native species that it can support, but also by the aesthetic and social benefits that can be derived. Therefore, we have focused on how lawn conversions may be best designed and managed to support both native biodiversity and the aesthetic and social needs of urban-dwelling human populations– specifically, when habitat fragments of native plants are added to an otherwise unsupportive matrix.

A limitation of this study is its narrow geographic scope, focused primarily on lawn conversions within the United States and parts of Europe. Future iterations should expand on this to include lawn conversion examples (or their small-scale urban equivalent) globally. Additionally, we limited our research to residential and neighborhood-scale urban restoration projects. Future studies should expand on this to include much larger scale urban ecological design projects, including lawn conversion efforts in parks, campuses, and greenways.

Further research is needed to develop a clear understanding of the different benefits and challenges of habitat restoration at the site scale in urban ecological design. This is important for a number of reasons: (1) so landscape architects can make good decisions on how to optimize habitat value in their designs; (2) so consumers can make good decisions that align impact with intention; and (3) so city planners and civic leaders (e.g., transportation and highway divisions, counties, fire agencies, water agencies) can be better informed on the ecological impacts of their projects. We need scientists to engage in studies at these scales [121]. There is a tremendous amount of research aimed at human-impacted systems, from agricultural systems to wildlife reserves. Yet small-scale interventions have largely (though not entirely) been ignored, despite the well-established ecological importance of native landscaping and growing interest in native plants in the landscaping industry.

We need to start viewing each lawn conversion as an opportunity to test ecological theory at the site scale. Ecological modelling and performative design testing can provide designers and ecologists opportunities to work together pre-construction and encourage the involvement of both [16]. A requirement for landscape performance metrics and ongoing ecological monitoring can similarly improve lawn conversion design and multidisciplinary engagement. This emphasis on ecological performance will likely lead to improved site-specific factual information that can subsequently be applied to the design of similar projects. We hope that future generations of ecologists will be motivated to include urban landscaping projects in their areas of research, supported by public and private investment.

Finally, the landscape architecture perspective reveals the importance of including design principles and community engagement opportunities within habitat restoration and conservation efforts. As the popularity of native plants continues to grow, the key to turning this momentum into restoration that is long-lasting and impactful will be helping to create a compelling visual narrative that individuals can connect with and support.

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Appendix A

Table A1. GLOSSARY.

Design Term	Definition	Ecology Term	Definition
Adaptability	Change and growth within natural and built environments in reaction to the actions of social and ecological forces	*Consilience*	Natural systems and human systems interact and alter one another, producing an energetic synthesis in the process.
Authenticity	The quality of a designed space that is real or true and accurately portrays the thing it is representing without being contrived or pre-prescribed	*Self-sustaining Restored Ecosystems*	Systems that require little or no human intervention or maintenance over the long term, in part due to suitable landscape and environmental contexts and exchanges
BIMBY—Biodiversity in My (Back) Yard	The contribution of residential front-yards to biodiversity, ecosystem services, and sustainability	*Stepping Stones*	Small unconnected patches of habitat that are close enough together to allow movement across the landscape
Built Environment	The man-made structures, features, and facilities viewed collectively as an environment in which people live and work	*Anthropogenic Landscapes*	Areas where direct human alteration of ecological processes is significant and directed toward servicing the needs of human populations for resources and services
Community Design	Multi-faceted approach to the planning, design and management of public spaces incorporating incites from local communities	*Stakeholder Restoration Objectives*	The process of incorporating stakeholder values and time considerations into ecological restoration decision-making processes
Complexity and Order	Patterns of aesthetic diversity and visual richness in the landscape	*Landscape Heterogeneity*	A landscape with a mix of concentrations of multiple species of plants

Table A1. *Cont.*

Design Term	Definition	Ecology Term	Definition
Design Concept	The core idea driving the design of a landscape, explained via a collection of sketches, images, and research	*Hypothesis*	A proposed explanation made on the basis of limited evidence as a starting point for further investigation
Design Process	The steps or approach taken in search for form or answers to design questions, typically undertaken through a four step-process: conceptual design, schematic design, design development, and construction documents	*Methods*	A concise description of the materials, procedures, and equipment used, including how the study was conducted, how data were collected, and what statistical and/or graphical analyses were undertaken
Design With Nature	An ecological approach pioneered by Ian McHarg integrating the sciences, arts, and planning that applied a suitability analysis ("layer-cake method") to the planning and design of communities	*Geographic Information System (GIS) Mapping Technology*	A system that creates, manages, analyzes, and maps all types of data, integrating location data with descriptive information
Drought-Tolerant	Able to tolerate very little to low-levels of water for certain periods of time and still thrive	*Xeric*	Characterized by, relating to, or requiring only a small amount of moisture
Ecological Gentrification	The implementation of an environmental planning agenda related to public green spaces that leads to the displacement or exclusion of the most economically vulnerable human population while espousing an environmental ethic	*Exploitation Competition*	Competition in which any adverse effects on an organism are brought about by reductions in resource levels caused by other competing organisms (on a first come first serve basis)
Ecological Urbanism	The concept that design is the key to balancing the conflicts between ecology (uninfluenced by humans) and the overt consumption of urbanism.	*Remediation*	Improving an existing ecosystem or creating a new one with the aim of replacing another that has deteriorated or been destroyed
Ecotone	A transition area between two plant communities, where two communities meet and integrate	*Edge Effect*	The effect of an abrupt transition between two quite different adjoining ecological communities on the numbers and kinds of organisms in the marginal habitat
Environmental Cosmopolitanism	The variety and vitality of urban ecosystems which include native, ornamental, and spontaneous urban plants; vibrant concentrations of global biodiversity	*Novel Ecosystems*	A system of abiotic, biotic, and social components (and their interactions) that, by virtue of human influence, differ from those that prevailed historically (Hobbs 2013)
Form and Structure	The shapes of objects in a landscape that help set the style, create the mood and carry the message of a garden	*Configuration*	The physical and spatial distribution of landscape elements
Garden	A piece of land where flowers and other plants are grown for cultivation, display, and enjoyment	*Biome*	The total complex of biotic communities occupying and characterizing a particular area
Genius Loci	Protective spirit of a place; a location's distinctive atmosphere	*Habitat Specialists*	Species that have evolved to survive only in a specific habitat
Green Infrastructure	Natural vegetative systems and green technologies that collectively provide society with a multitude of economic, environmental, health, and social benefits	*Constructed Ecologies*	Engineered systems featuring interacting living and non-living components, designed to produce valuable services
Guided Landscape Dynamics	A form of planting that is organic, curvilinear, casual, or seemingly spontaneous and often mimics natural patterns of growth and distribution to produce specific aesthetic or ecological effects	*Assisted Regeneration*	The intermediate restoration approach to facilitate the recovery process in sites that show some natural regeneration
Hardscape	Man-made structures and features on the ground-plane that are typically impermeable	*Abiotic*	Anything chemical or physical that lacks life
Heritage Landscape	A landscape, usually preserved in its original or enhanced state for its historical or cultural value	*Remnant Habitat*	An ecological community containing native flora and fauna that has not been significantly disturbed by destructive activities such as agriculture, logging, pollution, development, fire suppression, or non-native species invasion
Hypernature	An exaggerated version of nature that utilizes juxtaposition to make a landscape more capable of being noticed or of performing more resiliently	*Biodiversity Hotspots*	An area with a high percentage of plant life found nowhere else on the planet
Interstitial Spaces	In-between, unplanned, or abandoned spaces in urban areas, including spaces where planning and boundaries are unclear or non-existent such as underpasses, abandoned lots, and alleyways	*Fragmentation*	The transformation of a large expanse of habitat into a number of smaller patches isolated from each other by a matrix of habitats unlike the original
Landscape Performance	The measure of efficiency with which designed landscape solutions fulfill their intended purpose and contribute to sustainability	*Ecosystem Services*	A phrase commonly used to help quantify the economic benefits of conserving biodiversity
Landscape Urbanism	Design and construction based on ecological communities and hydrological patterns meant to repair and improve ravaged natural systems	*Ecosynthesis*	The use of introduced species to fill niches in a disrupted environment with the aim of increasing the speed of ecological restoration
Lawn Conversions	The replacement of turfgrass with drought-tolerant (often native) plants and other landscape materials	*Backyard Restorations*	The process of converting traditional residential landscapes such as lawns to those that attract and support native birds, bees, butterflies, and other wildlife.

Table A1. *Cont.*

Design Term	Definition	Ecology Term	Definition
Locus Amoenus	A lovely place, usually idealized	*Reference Ecosystems*	A community of organisms able to act as a model or benchmark for restoration
Mass Plantings	A design form where many plants of the same species are used to fill an area.	*Landscape Homogeneity*	A landscape with a lack of biodiversity
Matrix Planting	The underlying base layer of a garden where a single species, or handful of species, dominates the planting, forming a matrix into which other plants are blended	*Plant Distribution and Abundance*	The manner in which plants are spatially arranged and the number of individuals within a defined geographic area
Mixed Border	A garden with a mix of different plants such as flowers and shrubs	*Community*	An assemblage of various organisms living in the same environment
Naturalistic Urban Vegetation	Native plants used in urban landscapes	*Island Biogeography Theory*	Conserved areas and nature reserves are surrounded by an 'ocean' of habitat made unsuitable, and therefore hostile, by humans
Nature Rx	Initiatives encouraging healthcare providers to prescribe time in nature (cultivated and wild) to improve their patients' mental and physical health	*The Microbiome Rewilding Hypothesis*	The proposed return of human habitat to a state high in microbial diversity that in turn bolsters human health through disease prevention
Ornamental Plants	Plants that are grown for decorative purposes in gardens and landscape projects	*Exotic Vegetation*	A plant species that is not native to that ecosystem
Outdoor Rooms	Plantings that define spaces and are used to connect and extend the geometry, rhythms, and scale of buildings into the landscape	*Ecological Niche*	The relational position of a species or population in an ecosystem
Parametric Design	The use of computer assisted design (CAD) and 3D applications to test values associated with a site (physical, ecological, or social-cultural)	*Data-scaping*	A spatial representation of collected data of a site
Placemaking	A community engaged approach to the planning, design and management of public spaces that promote people's health, happiness, and well-being	*Nature Based Solutions*	Living solutions underpinned by natural processes and structures that are designed to address various environmental challenges while simultaneously providing multiple benefits to economy, society and ecological systems
Plant Palette	The range of plants included in a garden design	*Plant Community*	A collection or association of plant species within a designated geographical unit
Perception	A way of regarding, understanding, or interpreting a design; a mental impression	*Observation*	The organization, identification, and interpretation of sensory information in order to represent and understand the presented information or environment
Proportion and Scale	The relationship of plants and landscape elements to the surrounding area, and the size (and visual weight) of these elements compared to that of the human body	*Composition*	The relative proportion of habitat types in the landscape, regardless of spatial distribution
Repetition and Rhythm	Repeating colors, materials, or a specific component within a design to unconsciously build familiarity with a space	*Spatial patterns*	Regularities in what we observe in nature; the discernible outcomes or signatures of the processes operating in a given system
Resilience	Ability of a landscape to sustain desired ecological functions, robust native biodiversity, and critical landscape processes over time, under changing conditions, and despite multiple stressors and uncertainties.	*Mitigation*	Offsetting or countering the adverse environmental effects of developing land
Rewilding	A progressive approach to protecting an environment and returning it to its natural state	*Succession*	The process by which biological community composition recover over time following a disturbance event
Screening Plantings	Shrubs used to provide privacy, block a poor view, or as a natural boundary or barrier	*Hedgerow*	A row of bushes, trees, and plants, usually growing along a bank bordering a country road or between fields
Site Analysis	The process of researching and analyzing the social, historical, climatic, geographical, legal, and infrastructural characteristics of a given site	*Rapid Bioassessment*	A series of questions about an area developed to obtain considerable information in a short period of time
Site Visit	A visit to a design project to examine the site, observe the environment, and realize things previously drawn on paper in three-dimensional space	*Field Work*	The gathering of information about an area or ecosystem of interest in its natural environment, rather than in a place of study
Social Contagion	Residents imitate the landscaping of their neighbors	*Biomimicry*	Practice that learns from and mimics the strategies found in nature to solve human design challenges
Spontaneous Urban Plants	Vegetation that naturally occurs in untended urban areas	*Pioneer Species*	A species that's typically the first to colonize a barren ecosystem
Sustainable Development	The idea that human societies must live and meet their needs without compromising the ability of future generations to meet their own needs	*Habitat Enhancement*	The process of increasing the suitability of a site as habitat for some desired species.

Table A1. *Cont.*

Design Term	Definition	Ecology Term	Definition
Swath/Drift	A restricted palette of plants spread repeatedly throughout a landscape	*Patch*	Heterogeneous plant communities composed of a mosaic of single-species
Terrain vague	Open spaces and wild nature	*Biological Integrity*	A term associated with how "pristine" an environment is and its function relative to the potential or original state of an ecosystem before human alterations were imposed
Urban Greenway	Larger scale connected groupings of plants, lawns, green infrastructure and programmatic elements to ensure social and ecological connectivity	*Wildlife Corridor*	An area of habitat connecting wildlife populations separated by human activities or structures
Urban Nature Wasteland	Urban spaces that have been left to grow wild	*Brownfields*	A tract of land that has been developed for industrial purposes, polluted, and then abandoned
Vernacular Landscapes	The product of local custom, pragmatic adaptation to circumstances and unpredictable mobility	*Adaptively Managed Ecosystems*	The result of a process that combines assessment with management actions to incorporate system dynamics and achieve social objectives within a landscape
Weeds	Species from 'elsewhere' that causes harm to human economy or standard of living	*Invasive Species*	Any species that has recently expanded its realized niche to colonize a new biogeographical area

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