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Review

Lessons Learned from Chicago Wilderness—Implementing and Sustaining Conservation Management in an Urban Setting

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Abstract: We summarize the factors that shaped the biodiversity of Chicago and its hinterland and point out the conservation significance of these ecological systems, addressing why conservation of Chicago's biodiversity has importance locally and beyond. We highlight Chicago Wilderness (CW), a regional biodiversity conservation alliance committed to protecting nature and enriching the lives of the region's residents. Chicago Wilderness, with over 250 institutional members, has for over a decade coordinated the efforts of diverse institutions, including federal, state, and local agencies, public land-management agencies, conservation organizations, and scientific and cultural institutions. Chicago Wilderness is committed to using science and emerging knowledge as a foundation for its conservation work. CW has several specialist teams that promote an interdisciplinary approach to conservation; we focus on the work of the CW Science Team,

the one team with a research mission. The scientific investigations that are undertaken to provide a knowledge base for the work of Chicago Wilderness have drawn upon a wide variety of conservation paradigms, including that of resilience thinking, which we illustrate in a series of case studies.

Keywords: urban biodiversity; resilience; ecological restoration; conservation alliance

1. Introduction

With a population of 2.7 million, Chicago is the largest city in the US Midwest and the third largest in the country [1] The greater Metropolitan Statistical Area (MSA) to which Chicago belongs has a population of almost 9.5 million [2] The radical and rapid transformation of the landscape that has occurred over the past century and a half in order to accommodate a burgeoning population might suggest that Chicago is not a promising place to undertake large-scale conservation efforts. However, the region supports conservation programs that have received widespread local, national and international recognition. That significant biodiversity protection occurs in Chicago is, in part, a consequence of the region's climate and its evolutionary and ecological history. It is also the result of decisions made by people both before and after the settlement of the region by European and other non-indigenous populations (hereafter referred to as the "settlement" period). These decisions resulted in land protected from development and/or maintained to preserve the characteristic biodiversity of the area.

In this paper we provide an overview of the factors that shaped the biodiversity of the Chicago region and evaluate the conservation significance of these ecological systems. The history of land planning that resulted in the protection of open space in the Chicago region is described in some detail. We describe the work of Chicago Wilderness (CW), a regional biodiversity conservation alliance that emerged over a decade ago and that now has more than 250 institutional members, committed to protecting nature and enriching the lives of the region's residents. The lands and waters protected by CW member organizations now total nearly 370,000 acres, extending from southern Wisconsin through Chicago and its suburbs to southwestern Michigan. The Chicago Wilderness alliance is committed to using science and emerging knowledge as a foundation for its conservation work. Therefore, we close the paper by focusing on the work of the CW Science Team, which brings together natural and social scientists to conduct research on restoration and conservation as part of complex, coupled socio-ecological system. A valuable paradigm for the Science Team's interdisciplinary approach has been emerging tenets of resilience theory. By resilience we mean the amount of disturbance that a system can absorb without changing its basic structure (its "state") state [3,4].

2. Biodiversity in the Chicago Wilderness Region: History and Current Status

2.1. Shaped by Ice and Fire

The landforms of the Chicago region were largely shaped by glaciation events acting on layers of sedimentary rock laid down in ancient shallow seas. The post-glacial period, geologically termed the

Holocene, has persisted for the past 12,000 years; although there has been some variability it has been the relative stable climatic regime in which the social-ecological systems of the world have developed [5]. Poor management of the climatic, edaphic, hydrological and ecosystem feedbacks that maintain this state may result in a critical transition to a less desirable state [6]. Indeed, we may have already transitioned from the Holocene to the unambiguously human-dominated era of the Anthropocene [7]. There is a growing consensus on the magnitude of global environmental problems such as climate change and biodiversity loss. Nevertheless, on finer spatial and temporal scales, systems have historically exhibited dynamic change. For instance, vegetation states in a given region persist or shift depending upon system feedbacks at local scales [4]. Thus, ecological managers working at a regional scale must devise flexible, multi-scalar management strategies that sustain local systems while simultaneously mitigating potentially harmful effects of environmental changes occurring across more-global scales. We briefly describe the ecological history of the Chicago region as background to our description below of efforts to sustain the area's distinctive biodiversity.

Lake Michigan and the other Great Lakes formed as a result of the Wisconsin glacial advancement and retreat 16,000 years ago. The advance and retreat of the ice deposited gravel, sand, silt, clay and rocky debris throughout the region. The composition of soils and their drainage, a result of glaciation, has significantly impacted the Chicago region's biodiversity.

Climatic shifts have also influenced the successional development of the region's biodiversity. The climate of the region is continental, with winters characterized by periodic incursion of cold Arctic air and at least two or three major storm systems resulting in significant snow accumulation. Average temperatures in January are typically below 0 °C. Because of the relative flatness of the terrain, wind-chill effects can be significant. Summers are dominated by warm humid air originating from the Gulf of Mexico, with summer temperatures averaging above 27 °C. Temperatures in all seasons are also influenced by the proximity of Lake Michigan, second most voluminous of the Great Lakes, which produces a so-called lake effect, resulting in cooler temperature nearer the lake in summer and warmer breezes during the cold season (provided that the lake is not frozen, which has been the usual case in recent years). Precipitation totals 86 cm a year on average, most of it falling as rain in the summer months [8].

Considerable attention has been paid to reconstructing the post-glacial history of Illinois [9–11]. The initial tundra-like post-glacial vegetation was briefly replaced by spruce (*Picea*), which in turn was replaced by deciduous trees as temperatures increased. Temperatures and precipitation vacillated for several thousand of years, and vegetation responded with alternatively dominating conifers and deciduous trees. The landscape configuration familiar to contemporary observers, characterized by a patchwork of woodlands, prairie and wetlands, emerged about 8,500 BP. Although these patterns remained highly dynamic, xeric oak-hickory forest dominated in the immediate Chicago region (Northern Illinois). In the last several centuries the region has experienced cooling and xeric trends alternating with warming and more humid periods. In the years before the large-scale clearing of vegetation associated with the establishment and growth of Chicago, a warming trend increased the prevalence of deciduous vegetation.

The role of fire considered in the context of edaphic and climatic variability in configuring the landscape and maintaining disturbance-dependent habitats across northeast Illinois has been contested among academic ecologists over the course of the last hundred years. Even by the 1930s, when Edgar

Nelson Transeau wrote about the factors influencing the origins, development and maintenance of the Midwestern prairies, he could outline several competing hypotheses already extensively debated in the literature [12]; for instance, prairies as "scars" persisting after the ecological conditions producing them had terminated but maintained by human intervention; prairies as persisting because of unfavorable soil conditions ("immature soils"); prairies as the "pyrogenic victory of Indians and pre-Indians" who maintained the prairies as pasture and hunting ground. To this list one can add the role of large grazers, especially bison, in maintaining prairie vegetation [13]. Contemporary opinion is that the mixture of prairie, savanna, and forest vegetation in the Chicago region, the so-called "vegetation mosaic", is influenced by both climate and fire [13]. Research on the use of fire as a means of maintaining this mosaic has been prevalent since the 1960's. The use of prescribed fire remains contentious in the region and successful implementation requires negotiation with the local community [14].

2.2. "City of Big Shoulders": The Growth of Chicago and the Transformation of Natural Landscapes

The suitability of lands southwest of Lake Michigan for the growth of an urban center is attributable to many of the same factors that influence the region's ecological communities. The lakes and waterways provide an abundant supply of freshwater, the young post-glacial soils are fertile, and there is an abundant supply of accessible resources, including significant supplies of timber and mineral ores to the north in Wisconsin and Michigan. The early colonization of the region by European settlers was influenced by the region's proximity to a continental divide that provided portage between the Great Lakes and the Mississippi River and put Chicago at an important crossroads. Furthermore, Chicago is roughly located midway between pole and equator (coordinates 41°52′55″N 87°37′40″W) and its continental climates ensure relatively long and productive growing seasons. Despite the many ecological benefits, historian William Cronon [15] points out, that the precise location of the young city had numerous shortcomings primarily related to the marshy ground close to the lake, which required raising of the city in its early years to prevent streets from becoming water-logged due to frequent floods.

After its founding in 1832, Chicago's population growth was unprecedented. By 1890 it had become the third US city to have a population of 1,000,000 [16]. In 1900 it was the second most-populous city in the US. After 1900 the growth slowed but by this time there had been a major transformation of the region's landscapes. The exceptional climatic and edaphic favorableness of the Midwest for agriculture, combined with the Midwest's rapid population growth from the mid-nineteenth century, resulted in rapid transformation not only of lands proximate to the metropolitan areas, but of entire biomes in regions far from cities. Of the estimated 8.9 million hectares of prairie originally in Illinois, 930 hectares remain—a decline of 99.9% [17]. In less than a century most of the natural landscape had been ceded to domestic and industrial use in the city, and to agriculture in the hinterlands. Around the end of the 19th century there was growing recognition that some of the natural heritage of the region should be retained.

Though not as influential perhaps as market planners ("moneymaker" planning), public and private community planners in Chicago dedicated to making the city a "good" place to live developed programs to retain substantial open space in the young city and its hinterlands [18]. The *Plan of Chicago* in 1909 (the so-called Burnham Plan), though commissioned by the Chicago commercial

elite, is the most widely known culmination of such early efforts to ensure "that the city may be made an efficient instrument for providing all its people with the best possible conditions of living" (from the Plan of Chicago quoted in Smith) [19]. A central proposal of the plan was the "improvement" of the lake front by the construction of a shoreline parkway and the creation from largely undeveloped lands of the 1.3 km-long Grant Park. The plan also envisioned an outer park system, and made provisions for a system of widened streets and avenues. The majority of the open space set aside by planning efforts, however, was maintained as parks, often with formal gardens rather than representative remnants or examples of pre-settlement habitat.

In contrast to the parks, and more consequential for the conservation of the pre-settlement landscape was the creation of a system of forest preserves and conservation districts in the early years of the twentieth century. There are now 62,240 ha of land in this system across Chicago and surrounding counties [20]. The purpose of this system, as annunciated in the 1913 act that created them, has an explicit conservation focus—the land was to be acquired "for the purposes of protecting and preserving the flora, fauna and scenic beauties" and, furthermore, "to restore, restock, protect and preserve the natural forest and said lands together with their flora and fauna, as nearly as may be, in their natural state and condition, for the purposes of the education, pleasure, and recreation of the public"[21]. Although the various county forest preserves represent substantial tracts of land, and a few contain good examples of the original landscape, very little is regarded as "exceptional quality" habitat [20]. Indeed, land that was acquired and set aside a century or more ago has only relatively recently been managed for the preservation of the original biotic communities. Grazing, timber removal, fire suppression and other influences have resulted in a rapid shift of these landscapes from the ecological state at the time they were placed under protection. Although the composition and structure of biotic communities of the region have been, as we have seen, in dynamic flux since the end of glaciation, there has been very considerable change in recent decades are with consequent losses of much of the flora and fauna the preserves were established to protect. Since contemporary conservationists and land managers regard most of the land as being highly degraded, managers have been attempting to restore some of these lands to re-establish vegetation characteristic of the landscape that the early settlers encountered.

2.3. Ecological Communities of the Chicago Wilderness Region and Their Conservation Status

The Chicago Wilderness classification scheme recognizes seven different terrestrial community types: forest, savanna, shrubland, prairie, wetland, cliff, and lakeshore communities [22]. Each community type is finely subdivided; several sub-communities are recognized by the Nature Conservancy as *critically imperiled globally*. These include dry-mesic, mesic, and wet-mesic fine-textured soil savanna; dry-mesic fine-textured soil shrublands; wet-mesic woodlands; and wet-mesic sand shrublands. Many other sub-communities, including types of prairie, are classified in the Nature Conservancy's next most significant conservation category, *imperiled globally*. In addition to these endangered plant communities, the region also hosts animal assemblages of conservation significance—in fact, most rare plant communities have bird, reptile, amphibian and invertebrate assemblages of concern. Additionally, there are several rare mammal species targeted for conservation, including Franklin's ground squirrel, *Poliocitellus franklinii*.

Although there are extensive protected open lands throughout the Chicago Wilderness region (over 120,000 hectares), the rarer community types are scarce. The Illinois Natural Areas Inventory identified only 4,200 ha of land with significant natural characteristics throughout the entire state [23], which represents just seven-hundredths of one percent of the total land and water area of Illinois [24].

A recent report on the state of natural lands in the Chicago region concluded that the majority of the remaining natural areas surrounding Chicago are not healthy in terms of reflecting the pre-settlement state [24]. Reasonably well-characterized stressors, such as fragmentation associated with urban development, invasion by non-native species, overabundant deer populations, modified hydrological conditions, and fire suppression, have contributed to the decline in the quality of the region's natural plant communities and animal assemblages—and continue to threaten them.

2.4. A rationale for Biodiversity Conservation in the Chicago Metropolitan Area?

As stated above, the rationale for establishing a system of forest preserves around Chicago in 1913 was "for the purposes of the education, pleasure, and recreation of the public." Nevertheless, the Forest Preserves Statute recognized that many benefits to the urban population redound from the simple protection of nature. Written more than eighty years later, the Chicago Wilderness Biodiversity Recovery Plan (hereafter, Recovery Plan), a blueprint for contemporary conservation and restoration efforts, echoes this important principle [22]. The goal of the Recovery Plan "is to protect the natural communities of the Chicago region and to restore them to long-term viability, in order to enrich the quality of life of its citizens and to contribute to the preservation of global biodiversity" [22]. To emphasize: the purpose of protecting and restoring is both for the well-being of the region's human population, as well as being an effort on behalf of global conservation—for people and for the sake of the rest of nature. The Recovery Plan proceeds to present the case for the conservation and the proposed management of the region's biodiversity in both of these categories. Though industries dependent on the direct use of native species in the Chicago Wilderness region are presently non-existent, the Recovery Plan foresaw that the economic value of genetic material from such sources may increase. The provisioning of ecosystem services is presented in the plan as a second major indirect value derived from nature. The final direct-use value discussed is the recreational and aesthetic value of these lands.

In addition to the values that accrue directly to people from the protection of nature, the Burnham Plan recognizes, in concordance with the goal of the CW Biodiversity Recovery Plan, the *intrinsic* value of these systems, "the feelings of ethical obligation to protect other species from extinction, religious values associated with cherishing the Earth and its inhabitants…" [22] Though the discussion of the values of biodiversity conservation described in the Recovery Plan is generic, it does include some striking local examples of the types of ecosystem services derived from the protection of ecosystems. For example, it cites the cost of flooding on the Des Plaines River for local governments and property owners to be $20 million per annum, and associates this cost with the loss of wetlands which would otherwise ameliorate some of this flooding. Similarly the loss of habitat due to urbanization of the region arguably necessitates the Metropolitan Water Reclamation District's multi-billion dollar construction of the Tunnel and Reservoir Plan (TARP), known as the Deep Tunnel, the proposed solution to flooding in the Chicago area. Although the Biodiversity Recovery Plan reiterates many of the well-known arguments for conserving biodiversity, there are, however, two key

components worth stressing: (1) the Biodiversity Recovery Plan was a relatively early adopter of "ecosystem services" as a valuable framework in which to promote large-scale conservation efforts; and, (2) the distinction between the different motivations promoting conservation has led recently to research attempting to evaluate the trade-offs and synergies in using ecosystem services or species protection as a guide for management planning (see ULTRA-Ex, Appendix 2). These diverse ecological, social and economic values, as articulated in the foundational documents of Chicago Wilderness, are central to the activities of the alliance.

2.5. History of the Chicago Wilderness Alliance

Chicago Wilderness builds on the pioneering influences of architects, planners, and ecologists whose efforts eventually led to the establishment of the Forest Preserve District of Cook County in 1914. A number of additional factors contributed to the development of the alliance. Chicago gained some prominence, starting in the 1960s and 1970s, in the field of restoration ecology as some of the region's first prairie restorations were installed at the Morton Arboretum in Lisle, Illinois, and on the grounds of the Fermi National Accelerator Laboratory in Batavia, Illinois. Also, at this time, a burgeoning movement of volunteer-led land stewardship was gaining momentum through the efforts of volunteer groups along the North Branch of the Chicago River [25]. A widening segment of the general public also began to take note of local restoration efforts, and several conservation leaders saw the need to coordinate conservation and restoration activities on a regional scale.

In February 1993 representatives from thirteen conservation agencies and non-profits gathered to explore a possible partnership to address biodiversity conservation needs across the Chicago metropolitan landscape [26]. This initial conversation included federal and state agencies, county forest preserve districts, and non-profit organizations that seemingly recognized that collaboration and synergy would improve the management of the land. The directors of these agencies and organizations crafted a Memorandum of Understanding and formed the alliance's four teams: Science, Land Management (now called Natural Resources Management), Education, and Policy & Planning (now called Sustainability). Chicago Wilderness was publicly launched in April 1996 with an informal network of 34 founding organizations comprised of eight federal agencies, six county forest preserve and conservation districts, two state agencies, four regional and local agencies, and fourteen non-profit organizations. At the same time, the alliance announced the initiation of 28 regional biodiversity conservation projects due to a $700,000 grant from the US Forest Service [26]. Today the alliance is comprised of 258 organizations. The geography of Chicago Wilderness has expanded as well. Originally based on a much smaller region defined by nine counties (six in Illinois, two in Indiana, and one in Wisconsin), the current region is biogeographically based, spans four states encompasses 34 counties, and includes more than 1,460 km^2 of protected open space. Currently the work of the alliance is organized around four core strategic initiatives (See Appendix 1 for details).

3. Addressing Contemporary Challenges

The complexity of the challenges facing the Chicago Wilderness Science Team is embodied in the very name of the alliance. How do scientists help create and conserve a resilient urban "wilderness" in the age of the Anthropocene? Emergence of the rapidly changing Anthropocene from the more-stable Holocene is now recognized by popular publications such as *The Economist* [27]). The term captures

the sense that humans are a disruptive biogeochemical force whose impacts are now felt on a global scale. If wilderness protection is the paradigmatic conservation strategy of the last century, restoration ecology may well be the strategy of the Anthropocene. The CW Science Team is helping to promote an interdisciplinary focus on restoration as the engineering of nature, one especially integral to dynamic metropolitan socio-ecological systems. The Science Team explicitly views restoration as management of a coupled social-ecological system (SES). We give some examples in Appendix 2 to illustrate this approach.

3.1. The Ecological Challenge of Implementing Restoration Management in the Region

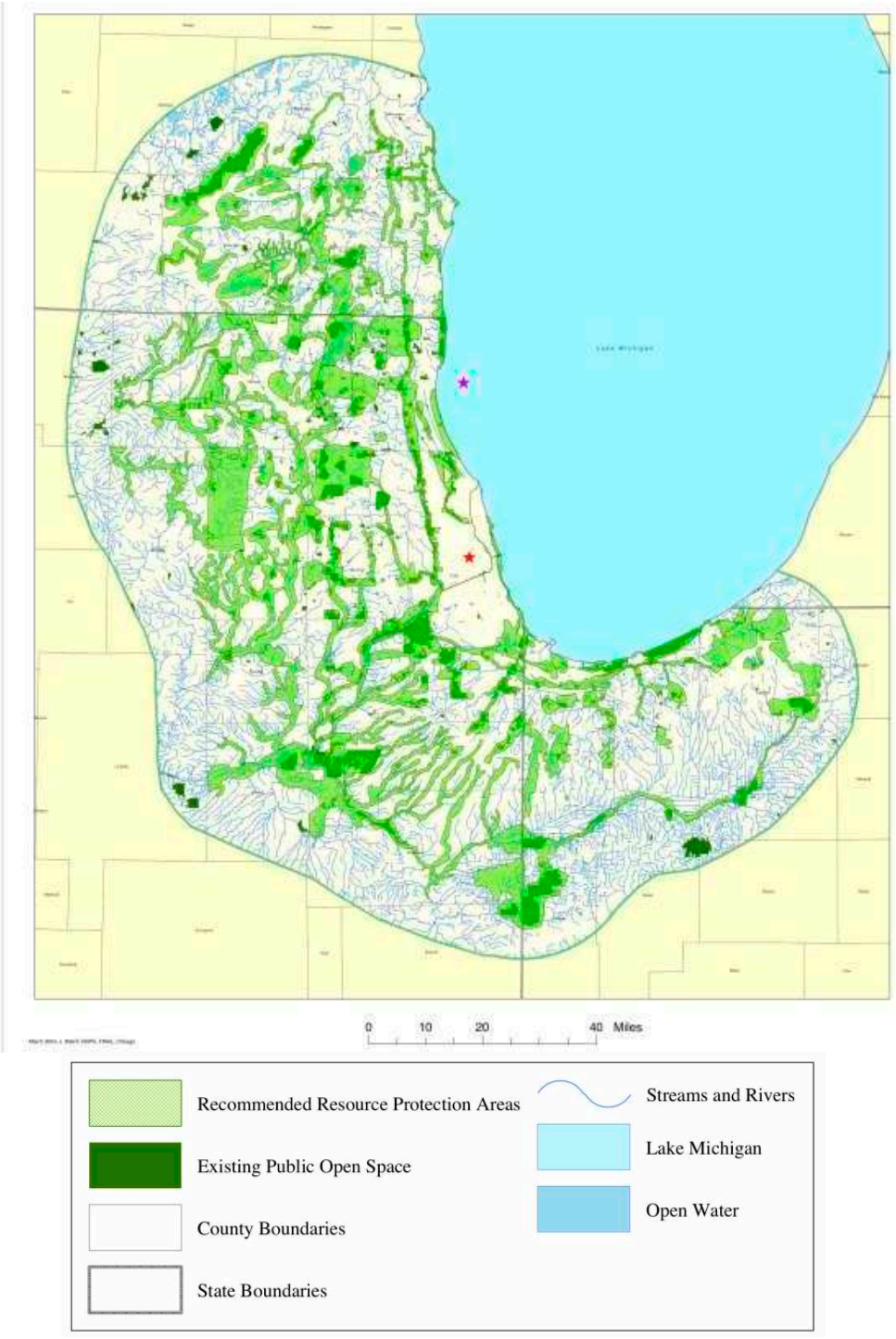
Ecologists and social scientists of the CW Science Team face two basic challenges as members of the restoration community. The first is to help define the goal of restoration; the second is to provide guidance in achieving the agreed-upon goal [28,29]. This is no straightforward task, because there is no universal agreement on restoration goals by managers, the public, and scientists. Informally, an original goal of ecological restoration in the Chicago Wilderness had generally been stated as returning the land to the native flora and fauna of pre-settlement. With this in mind there were significant efforts to develop a detailed understanding of the pre-settlement vegetation. Especially helpful was the work of Marlin Bowles and Jenny McBride, of the Morton Arboretum, who used U.S. Public Land Survey (1821–1840) records to reconstruct the pre-settlement vegetation of the region [30]. Although an understanding of pre-settlement systems has been an important guide to management, attempting to re-create a faithful replica of this former state is no longer regarded by land managers as either a logistically or ecologically realistic goal. Reliance on pre-settlement conditions as a restoration guide arguably likely reduces system resilience in the same way that managing for maximum sustainable yield, a term prevalent in forest management literature, reduces resilience, since it attempts to confine the system's dynamics by blocking feedbacks that would otherwise have promoted change [31]. Research in support of restoration by the CW Science Team is guided by the restoration definition promoted by the Society for Ecological Restoration: "Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" [32]. The definition, along with SER's attributes of restored systems, does not make explicit reference to the faithful reproduction of historical conditions but implies a notion of ecological "health" which is translated in the Chicago Wilderness alliance as a suite of strategies that focus largely on the conservation of the biodiversity in the region.

The Chicago Wilderness Biodiversity Recovery Plan identified the primary factors contributing to the relatively poor ecological quality of the region's biodiversity [22]. The fragmentation of urban habitat, invasion of non-native species (and in some cases native weedy species), fire suppression and so forth, all contribute to the fact that much of the protected open lands is degraded [24]. Specific restoration challenges are substantial (though certainly not unique to the CW region): removing and preventing reinvasion by problem species such as European buckthorn (*Rhamnus cathartica*) in woodland and savanna habitats; restoring pre-development hydrology; managing migration rates between conserved patches, and establishing buffer zones around targeted lands in a fragmented landscape that is subject to pressures of urbanization in a large metropolitan area (see Figure 1 for the CW Green Infrastructure Vision); and marshalling support for controversial management techniques. Contentious management approaches are also not unique to the Chicago region and include the removal

of mature trees to create savanna; removal of invasive shrubs, such as buckthorn, that are viewed by some as desirable visual buffers; use of fire near residences; and culling of deer populations. In the face of these very considerable challenges, the Biodiversity Recovery Plan not only is committed to improving the ecological condition of these systems, but also to restoring them to "long-term viability." The challenge of long-term viability is an especially difficult one, however, since even restored sites require extensive ongoing management in order to sustain the more desired plant and animal species [33]. Although restorationists recognize that management is a long-term endeavor, it may be possible to institute more effective and efficient strategies by reframing the challenges in the context of resilience theory. We call this Resilience Oriented Management (ROM), and provide two examples to illustrate. Taking a resilience approach to restoration management in the region might be helpful as a way of addressing challenges for both the governance of conservation lands and for the development of restoration management approaches that increase the efficacy of restoration.

Example 1: Alterations to pre-settlement disturbance regimes associated with the rapid development of the Chicago region had major implications for the region's ecosystems [34,35]. For example, the phenomenon of tree and shrub invasion into grassland and savanna, associated with changes in historical disturbance cycles, is globally commonplace [36], though it has regional implications. The phenomenon is typically examined from the perspective of a single dominant feedback process, namely fire [37,38], though there is recognition that such encroachment is regulated by multiple factors [39,40]. In the Chicago Wilderness region, post-settlement suppression of fire in prairies generally resulted in an invasion of woody vegetation, although the timing of the invasion can vary. In their study of a prairie-savanna in the Indiana Dunes National Lakeshore along the southern shore of Lake Michigan, Cole and Taylor [41] found that even after fire suppression, occasionally flooded patches still retained prairie as did areas on exposed south and southwesterly slopes. Thus the feedbacks maintaining a system in a particular regime are complex, and factors other than fire, for instance hydrological and edaphic, can determine the state of the system. After fire frequency changes, both the trajectory and the rate of successional changes are not always predictable. Managers have to employ restoration strategies that address both changes in the composition of the ecological community, for instance by removing woody invaders, and changes in feedback processes that sustain the restored state, such as fire. Research by ecologists to understand the resilience of both favorable states (e.g., a remnant prairie) or less desirable states (e.g., a site encroached by woody invaders) is likely to be useful to land managers. The Chicago Wilderness Biodiversity Recovery Plan, in calling for restoring "long-term viability," is arguing that community structure and the ecosystem feedbacks that help maintain it should be managed in a way that allows the system to persist in the restored state with minimum future inputs.

Figure 1. The Chicago Wilderness Green Infrastructure Vision (GIV): the GIV identifies 1.8 million acres of Recommended Resource Protection Areas associated with already protected public lands—spanning from southeast Wisconsin, through northeast Illinois into northwest Indiana and southwest Michigan. Green infrastructure is defined as the interconnected network of land and water that support biodiversity and provides habitat for diverse communities of native flora and fauna at the regional scale. It includes large complexes of remnant woodlands, savannas, prairies, wetlands, lakes, stream corridors, and the related natural communities that have been identified in the Biodiversity Recovery Plan. Green infrastructure may also include areas adjacent to and connecting these remnant natural communities that provide both buffers and opportunities for ecosystem restoration.



Example 2 Restoration approaches that change community structure, for example, by removing invasive shrubs, on the assumption that ecosystem processes will passively follow can be hindered if key ecosystem processes have not been restored. This may even be the case where managers have faithfully re-established historical abiotic conditions. Such an outcome can occur because the historical system has transitioned to a new state and is therefore in a highly resilient but degraded condition [42]. An understanding of alternative stable states, system thresholds and feedbacks into restoration management *sensu* Suding could be usefully applied to the problem of the encroachment of woody invaders in woodlands of the Chicago area [42]. One of the dominant invasive species in this habitat is European buckthorn, which was introduced into the region in the late 19th Century and now ranks among the most prevalent woody plants of the region [43]. Although the shrub is targeted for removal in most restoration projects, it can rapidly reinvade areas that are not continually intensively managed. There is some evidence that the shrub alters a range of soil properties [44,45], which may contribute to the rapid reinvasion. If the degraded woodland represents a relatively stable state, even restoring the conditions to those which formerly had supported the historical vegetation at a site may not result in a return to the desired vegetation. In order to effect a transition to the desired restoration goal it may be necessary to modify feedback conditions to a point where only that desired state can exist. The CW Science Team is currently investigating such "extreme" restoration approaches in the region. These resilience-oriented management strategies include the use of carbon amendments to reduce the availably of nitrogen in soils, with a view to promoting the competitive advantage of native over weedy invasive species [46,47].

3.2. The Challenge of Climate Change

The capacity of the human actors in social-ecological systems to manage resilience is termed adaptability [5]. Humans are fundamentally future-directed organisms, having a capacity for planning which then has implications for other entities [48]. Planning and governance arrangements (*i.e.*, institutions, or rules and norms of human behavior) can be regarded as a feedback in social-ecological systems. The adaptability of such arrangements can crucially influence the resilience of these systems. The contemporary challenge of climate change has both ecological and institutional components. Climate change seriously impacts the potential of reaching the Chicago Wilderness goal to protect and enhance biodiversity in the Chicago region and therefore represents a fundamental governance challenge.

The response of the Chicago Wilderness alliance to climate change was founded in the plan-development process that was begun with the writing of its Biodiversity Recovery Plan. Member institutions with expertise in the science of climate change stepped forward to coordinate a planning process with ample opportunity for input and feedback from all Chicago Wilderness members. The resulting Climate Action Plan for Nature (hereafter, Action Plan) outlines policy and management steps that can be taken to mitigate and adapt to both existing impacts and anticipated impacts of climate change [49] For example, the Action Plan explores the possibility of assisted migration for plants and animals of conservation interest. The Chicago urban area is a formidable obstacle to migration for many species, creating interest in the prospects for assisted migration. In this way, the move to a new—and desirable—resilient state may be facilitated even within a complex urban matrix like the Chicago Wilderness region.

Many Chicago Wilderness members hunger for information and ideas about how to manage their holdings in the face of climate change. Thus, information from the Climate Action Plan for Nature is disseminated in Climate Clinics. Clinics are an outreach and engagement tool to disseminate information and help communities and organizations increase their capacity to implement strategies of the Green Infrastructure Vision and the Climate Action Plan for Nature. This approach is designed to help managers take action to maintain the natural communities and the ecosystem services they provide within the Chicago Wilderness region. By working together in climate clinics and other climate-change related actions, Chicago Wilderness members are making choices about how to respond, and about the future they wish to see for the landscape. In this way, Chicago Wilderness members exhibit social resilience in the face of significant system change in the natural areas they manage and care for.

4. Summary

A major shift in world view of those involved in biodiversity management in a metropolitan setting seems necessary. Such a shift would move us from being outside observers of non-human Nature to observers and participants in Nature as a coupled social-ecological system. Traditionally the scientific challenges of managing biodiversity have been framed purely in ecological terms. The CW Science Team takes a broader view. It includes both natural and social scientists who jointly investigate regional challenges. The collaboration of natural and social scientists is designed to produce a more resilient organization, one that will be better able to deal with newly evolving definitions of Nature, and that will be better able to interact effectively with managers, policy makers and the public. A resilience framework is useful for evaluating the growth, development and persistence of the institutional collaboration of Chicago Wilderness. The coalition leadership helps the institutions of the region to span several scales of governance (e.g., from local decentralized volunteer activity, to larger scale management by the Forest Preserves), to facilitate networking, to integrate and communicate findings to all levels of the alliance, and to investigate and facilitate problem solving. That is, it behaves in many of the ways advocated by those who would apply resilience thinking to institutional governance [50]. Finally, in our thinking about Chicago Wilderness as a social-ecological system, we recognize that it may serve as a model where the intra- and inter-institutional interactions shape regional biodiversity, which in turn affects the people living in the Chicagoland area. The work itself produced by Chicago Wilderness can benefit from this resilience framework, but in turn, because of the extensive nature of conservation efforts in the region, a case study of the region can contribute to refining the use of resilience as a lens for viewing the management of resources in metropolitan settings.

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References

1. *U.S. Census Bureau Delivers Illinois' 2010 Census Population Totals, Including First Look at Race and Hispanic Origin Data for Legislative Redistricting*; U.S. Census Bureau: Washington, DC, USA, 15 February 2011. Available online: http://2010.census.gov/news/releases/operations/cb11-cn31.html (accessed on 12 February 2012).
2. Mackun, P.; Wilson, S. Population distribution and change: 2000 to 2010; U.S. Census Bureau: Washington, DC, USA, 2011. Available online: http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf (accessed on 12 February 2012).
3. Holling, C.S. Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.* **1973**, *4*, 1–23.
4. Walker, B.; Salt, D. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*; Island Press: Washington, DC, USA, 2006.
5. Folke, C.; Carpenter, S.R.; Walker, B.; Scheffer, M.; Chapin, T.; Rockstrom, J. Resilience thinking: Integrating resilience, adaptability and transformability. *Ecol. Soc.* **2010**, *15*, Article 20.
6. Scheffer, M. *Critical Transitions in Nature and Society*; Princeton University Press: Princeton, NJ, USA, 2009.
7. Crutzen, P.; Stoermer, E.F. The Anthropocene. *Glob. Change Newsl.* **2000**, *41*, 17–18.
8. Greenberg, J. *A Natural History of the Chicago Region*; University of Chicago Press: Chicago, IL, USA, 2002.
9. King, J.E. Late Quaternary vegetational history of Illinois. *Ecol. Monogr.* **1981**, *51*, 43–62.
10. Baker, R.G.; Sullivan, A.E.; Hallberg, G.R.; Horton, D.G. Vegetational changes in Western Illinois during the onset of late Wisconsinan Glaciation. *Ecology* **1989**, *70*, 1363–1376.
11. Nelson, D.M.; Hu, F.S.; Grimm, E.C.; Curry, B.B.; Slate, J.E. The influence of aridity and fire on holocene prairie communities in the eastern prairie peninsula. *Ecology* **2006**, *87*, 2523–2536.
12. Transeau, E.N. The prairie peninsula. *Ecology* **1935**, *16*, 423–437.
13. Anderson, R.C. Evolution and origin of the central grassland of north america: Climate, fire, and mammalian grazers. *J. Torrey Bot. Soc.* **2006**, *133*, 626–647.
14. Gobster, P.H. Introduction: Urban ecological restoration. *Nat. Cult.* **2010**, *5*, 227–230.
15. Cronon, W. *Nature's Metropolis: Chicago and the Great West*; W. W. Norton & Company: New York, NY, USA, 1992.
16. Nugent, W. Demography: Chicago as a modern world city. In *The Encyclopedia of Chicago*; Grossmann, J.R., Keating, A.D., Reiff, J.L., Eds.; The University of Chicago Press: Chicago, IL, USA, 2004. Available online: http://encyclopedia.chicagohistory.org/pages/962.html (accessed on 12 February 2012).
17. Steinauer, E.M.; Collins, S.L. Prairie ecology: The tallgrass prairie. In *Prairie Conservation-Preserving North America's Most Endangered Ecosystem*; Samson, F.B., Knopf, F.L., Eds.; Island Press: Washington, DC, USA, 1996; pp. 39–52.
18. Abbott, C. Planning Chicago. In *The Encyclopedia of Chicago*; Grossmann, J.R., Keating, A.D., Reiff, J.L., Eds.; The University of Chicago Press: Chicago, IL, USA, 2004; pp. 613–617.
19. Smith, C. *The Plan of Chicago: Daniel Burnham and the Remaking of the American City*; The University of Chicago Press: Chicago, IL, USA, 2006.
20. Packard, S. Forest preserves. In *The Encyclopedia of Chicago*; Grossmann, J.R., Keating, A.D., Reiff, J.L., Eds.; The University of Chicago Press: Chicago, IL, USA, 2004.

21. *The Early History of the Forest Preserve District of Cook County, 1869–1922*; Thornton, R.C., Ed.; Forest Preserve District of Cook County: River Forest, IL, USA. Available online: http://fpdcc.com/about/history (accessed on 12 February 2012).
22. *Biodiversity Recovery Plan*; Chicago Region Biodiversity Council: Chicago, IL, USA, 1999.
23. White, J. *Illinois Natural Areas Inventory Technical Report*; Department of Landscape Architecture, University of Illinois, Urbana-Champaign, and Natural Land Institute: Rockford, IL, USA, 1978.
24. Consortium, T.C.W. *The State of Our Chicago Wilderness: A Report Card on the Ecological Health of the Region*; The Chicago Wilderness Consortium: Chicago, IL, USA, 2006; p. 167.
25. Stevens, W.K. *Miracle Under the Oaks: The Revival of Nature in America*; Pocket: New York, NY, USA, 1996.
26. Ross, L. The chicago wilderness: A coalition for urban conservation. *Restor. Manag. Notes* **1997**, *15*, 17–24.
27. Welcome to the Anthropocene, Humans have changed the way the world works. Now they have to change the way they think about it, too. *The Economist*, 26 May 2011. Available online: http://www.economist.com/node/18744401 (accessed on 12 February 2012).
28. Ehrenfeld, J.-G. Defining the limits of restoration: The need for realistic goals. *Restor. Ecol.* **2000**, *8*, 2–9.
29. Choi, Y.D. Restoration ecology to the future: A call for new paradigm. *Restor. Ecol.* **2007**, *15*, 351–353.
30. Bowles, M.; McBride, J.; Bell, L. *Landscape Vegetation Pattern, Composition & Structure of Dupage County, Illinois, as Recorded by the U.S. Public Land Survey (1821–1840)*; Report to the Dupage County Forest Preserve District, Chicago Wilderness, Fish & Wildlife Service & Max Mcgraw Wildlife Foundation; The Morton Arboretum, Lisle, IL, USA, 1998.
31. Berkes, F.; Folke, C. Linking social and ecological systems for resilience and sustainability. In *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*; Berkes, F., Folke, C., Eds.; Cambridge University Press: Cambridge, UK, 1998.
32. Clewell, A.; Aronson, J.; Winterhalder, K. *The ser International Primer on Ecological Restoration*; Society for Ecological Restoration International Science & Policy Working Group: Washington, DC, USA, 2004. Available online: http://www.ser.org/pdf/primer3.pdf (accessed on 17 July 2011).
33. Hobbs, R.J. Setting effective and realistic restoration goals: Key directions for research. *Restor. Ecol.* **2007**, *15*, 354–357.
34. Bowles, M.L.; McBride, J.L.; Stoynoff, N.; Johnson, K. Temporal changes in vegetation composition and structure in a fire-managed prairie fen. *Nat. Areas J.* **1996**, *16*, 275–288.
35. Bowles, M.L.; McBride, J.L. Vegetation composition, structure, and chronological change in a decadent midwestern north american savanna remnant. *Nat. Areas J.* **1998**, *18*, 14–27.
36. Auken, O.W.V. Shrub invasions of north american semiarid grasslands. *Annu. Rev. Ecol. Syst.* **2000**, *31*, 197–215.
37. Heisler, J.L.; Briggs, J.M.; Knapp, A.K.; Blair, J.M.; Seery, A. Direct and indirect effects of fire on shrub density and aboveground productivity in a mesic grassland. *Ecology* **2004**, *85*, 2245–2257.

38. Robertson, P.A.; Heikens, A.L. Fire frequency in oak-hickory forests of Southern Illinois. *Castanea* **1994**, *59*, 286–291.
39. Bachelet, D.; Lenihan, J.M.; Daly, C.; Neilson, R.P. Interactions between fire, grazing and climate change at wind cave national park, sd. *Ecol. Model.* **2000**, *134*, 229–244.
40. Kennedy, P.G.; Sousa, W.P. Forest encroachment into a californian grassland: Examining the simultaneous effects of facilitation and competition on tree seedling recruitment. *Oecologia* **2006**, *148*, 464–474.
41 Cole, K.L.; Taylor, R.S. Past and current trends of change in a dune prairie/oak savanna reconstructed through a multiple-scale history. *J. Veg. Sci.* **1995**, *6*, 399–410.
42. Suding, K.N.; Gross, K.L.; Houseman, G.R. Alternative states and positive feedbacks in restoration ecology. *Trends Ecol. Evol.* **2004**, *19*, 46–53.
43. Glennemeier, K. The state of our wooded lands: Results from the Chicago wilderness woods audit. *Chicago Wilderness J.* **2004**, *2*, 16–22.
44. Heneghan, L.; Steffen, J.; Fagen, K. Interactions of an introduced shrub and introduced earthworms in an illinois urban woodland: Impact on leaf litter decomposition. *Pedobiologia* **2006**, *50*, 543–551.
45. Heneghan, L.; Fatemi, F.; Umek, L.; Grady, K.; Fagen, K.; Workman, M. The invasive shrub European Buckthorn (Rhamnus *cathartica*, L.) alters soil properties in midwestern US woodlands. *Appl. Soil Ecol.* **2006**, *32*, 142–148.
46. Blumenthal, D.M.; Jordan, N.R.; Russelle, M.P. Soil carbon addition controls weeds and facilitates prairie restoration. *Ecol. Appl.* **2003**, *13*, 605–615.
47 Averett, J.M.; Klips, R.A.; Nave, L.E.; Frey, S.D.; Curtis, P.S. Effects of soil carbon amendment on nitrogen availability and plant growth in an experimental tallgrass prairie restoration. *Restor. Ecol.* **2004**, *12*, 568–574.
48. Heidegger, M. *Being and Time, Trans*; Macquarrie, J., Robinson, E., Eds.; SCM Press: London, UK, 1927.
49. *Chicago Wilderness Climate Action Plan for Nature*; Chicago Wilderness: Chicago, IL, USA, 2010. Available online: http://www.chicagowilderness.org/pdf/Climate_Action_Plan_for_ Nature.pdf (accessed on 12 February 2012).
50. Olsson, P.; Gunderson, L.H.; Carpenter, S.R.; Ryan, P.; Lebel, L.; Folke, C.; Holling, C.S. Shooting the rapids: Navigating transitions to adaptive governance of social-ecological systems. *Ecol. Soc.* **2006**, *1*, Article 18.
51. Heneghan, L.; Umek, L.; Bernau, B.; Grady, K.; Iatropulos, J.; Jabon, D.; Workman, M. Ecological research can augment restoration practice in urban areas degraded by invasive species—Examples from Chicago Wilderness. *Urban Ecosyst.* **2009**, *12*, 63–77.

Appendix

Appendix 1. The Four Pillars of Chicago Wilderness Work

Chicago Wilderness focuses its efforts within four strategic initiatives:

A1.1. Implementation of the Chicago Wilderness Green Infrastructure Vision

Developed in 2004, the Green Infrastructure Vision (GIV) is a map-based representation of the goals of the Chicago Wilderness Biodiversity Recovery Plan (See Figure 1). The GIV identifies over 1.8 million acres of Recommended Resource Protection Areas (RRPAs) that surround, and/or connect the already protected core areas (1,460 km^2). The GIV serves as a macro-scale guide to focus land and water preservation and sustainable land-use practices. Implementing the GIV is a coordinated effort involving all alliance members in targeted community engagement.

A1.2. Leave No Child Inside

The Chicago Wilderness Leave No Child Inside (LNCI) initiative seeks to reconnect the region's residents, in particular children and their caregivers, with the natural world. The initiative does this through public outreach and awareness efforts, and by working with CW member organizations to provide nature-based programming and experiential opportunities.

A1.3. Natural Area Restoration & Management

Ecological restoration and management is a significant component of the work of Chicago Wilderness members. Within this initiative, Chicago Wilderness is working to identify and advance regional goals and strategic actions related to the preservation, restoration, and/or management of natural plant and animal communities; establish opportunities to promote the exchange of information on best-management practices; facilitate the implementation of regional-scale restoration and management projects; and identify and secure restoration and management resources for the Chicago Wilderness region.

A1.4. Climate Change

Recognizing the potential for climate change to jeopardize the conservation community's collective investments in the region, Chicago Wilderness developed its Climate Action Plan for Nature (CAPN) in 2010 to guide the alliance's work in preparing for and mitigating the impacts of climate change on regional biodiversity. The CAPN identifies goals and broad strategies in the areas of adaptation, mitigation and education.

Appendix 2. Addressing the Challenges: Current Research Projects of the CW Science Team

The Chicago Wilderness Science Team works to strengthen the scientific basis of biodiversity management in the region by implementing, and developing further, the CW Research Agenda, a white paper developed from 2006–2008 to guide the development of the research program [51]. The Science Team's mission is to provide scientific advice to land managers and foster region-wide communication and cooperation within the research community.

Through collaboration with land managers and CW alliance members, the Science Team has developed a suite of complementary research projects designed to enhance regional conservation and

ecological restoration research. The Science Team utilizes a suite of broadly interdisciplinary theories, methodologies, and partnerships. Building upon ongoing efforts that provide a base for recruiting new researchers, the Science Team seeks to strengthen linkages between the science and the practice of ecological restoration, and foster dynamic engagement between the linked human and natural systems of the region.

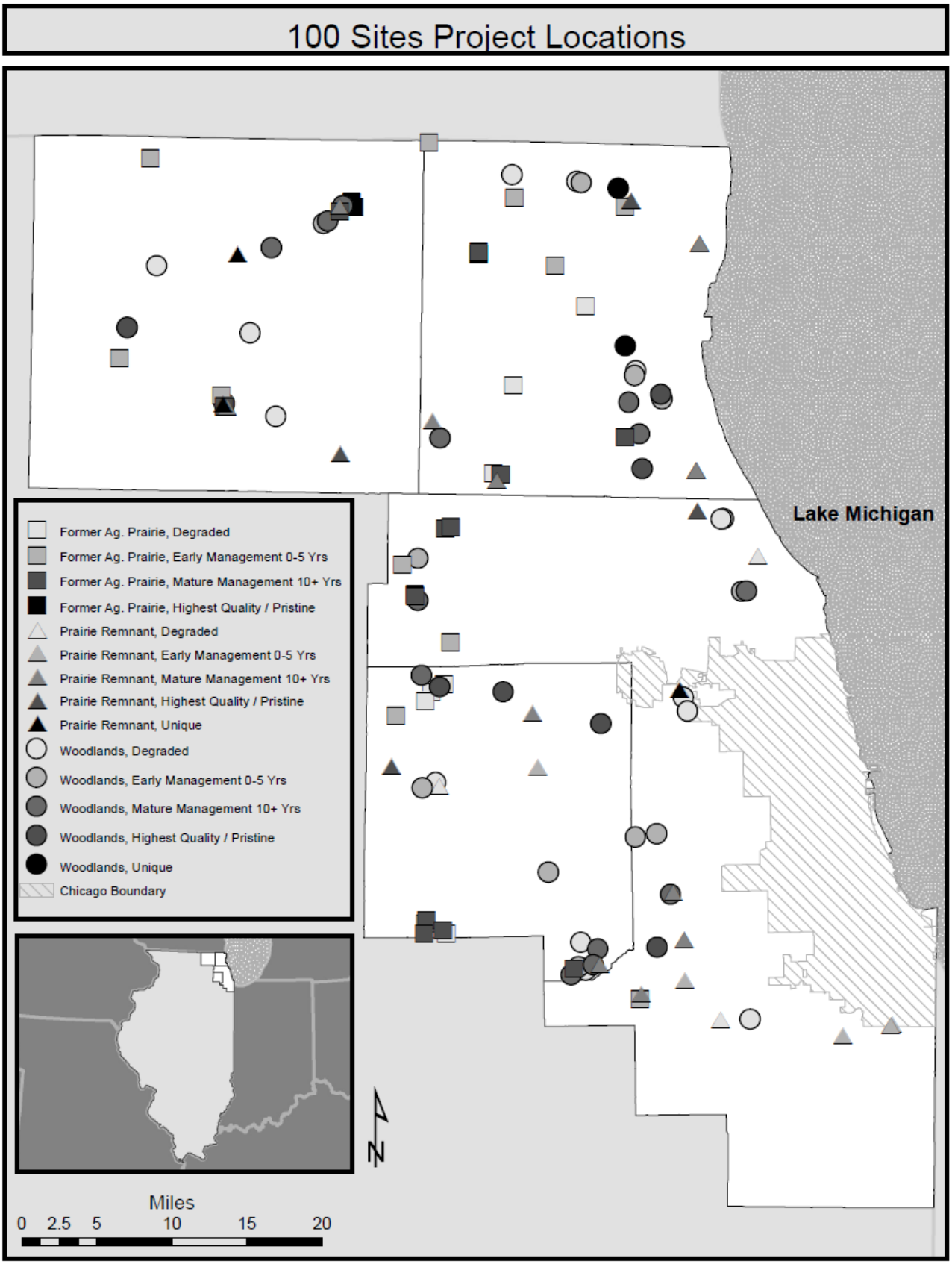
A2.1. Chicago Wilderness Land Management Research Program or, "100 Sites for 100 Years"

Funded by the Gaylord and Dorothy Donnelley Foundation, the "100 Sites" project is a unique collaborative effort between academic ecologists and land managers. This project addresses two main questions that relate to current outcomes of restoration efforts: How effective are current management practices for restoring and conserving biodiversity? How effective are current management practices for rehabilitating key ecosystem processes? In addition, this program has prepared the groundwork for addressing questions into the future. It has established over 100 sites that will be maintained at current management regimes for many years (maybe not a hundred, but that's our idealistic goal), with the goal of uncovering long-term trends in management outcomes that will appear with climate change and changing influences of urbanization.

To examine biodiversity and a suite of ecosystem processes associated with restoration management, the projectEstablished over 100 one-hectare long-term study plots in four CW counties (Figure A1). The sites are representative woodland, savanna and prairie habitats, and have been selected along gradients of management effort, from those that are highly degraded, usually due to impacts of invasive species, to mature restoration sites that have been managed for several years. We have also included sites that represent the "highest quality/pristine" habitats in the region as well as sites of particular interest to county land managers. Since it arranges ongoing management efforts in an explicit experimental design, the 100 Sites Project will provide ongoing assistance to adaptive management of the region's biodiversity.

Data gathered at these sites (including vegetation, nutrient availability, invasion by non-native earthworms, soil/litter arthropods, pollinators, and an assessment of bird communities) will be used to evaluate the effectiveness of biodiversity management practices, allowing us to validate (where appropriate), and improve and invent (where necessary), the most effective restoration practices for the Chicago region. A secondary goal of this project is to attract regional researchers and graduate students to conduct ecological studies locally. Similar to the structure of the Chicago Wilderness Alliance, collaboration and diversity of ecological researchers, all focusing on a common question of the impacts of restoration on ecosystem properties, will contribute to the long-term scope and sustainability of the project.

Figure A1. "100 Sites for 100 Years" This map show the distribution across the Chicagoland region of 100 one-hectare sites which are part of our "natural experiment" examining adaptive management.



A2.2. R.E.S.T.O.R.E.

Funded by the National Science Foundation's Coupled Natural and Human Systems program, RESTORE (Rethinking Ecological and Social Theories of Restoration Ecology) is an interdisciplinary project that combines the social and ecological sciences in order to investigate the connections and feedbacks between the human component and other-species components of biodiversity conservation. The project investigates, at organizational and site-specific levels, the different processes by which decisions are made about how to restore particular sites. It then seeks to understand whether different processes lead to actions that result in different biodiversity outcomes, and whether these different outcomes in turn influence the extent to which the public—recreation users and neighbors living near the natural areas— supports restoration and management activities.

The study focuses on oak-dominated woodlands and savannas that have undergone some form of management for at least five years. We selected sites that are managed by organizations representing a diversity of management structures and approaches—from large county-wide Forest Preserve Districts, to small land trusts, to public aboreta. In some cases decisions on how to restore and manage a site are made entirely by managers, whereas in others, volunteers play a role in deciding how to restore a site. Organizations managing the natural areas included in this study represent a broad spectrum of collaborative decision-making relationships.

Five specific objectives guide the project:

(1). Create an Agent-Based Model to understand interactions in collective decision-making processes.
(2). Investigate the perceptions, motivations, and institutions influencing management decisions and the organizational structure within which decisions are made.
(3). Document the range of biodiversity outcomes in a subset of oak-dominated woodlands and savannas undergoing restoration in Chicago Wilderness.
(4). Compare/contrast the relationship between distinct models of the planning processes and biodiversity outcomes.
(5). Investigate the relationships between restoration management decisions and the viewpoints of neighbors living in proximity to natural areas and natural-area users towards restoration.

A2.3. Chicago ULTRA-Ex

Funded by NSF and the US Forest Service, the ULTRA-Ex project (Urban Long-Term Research Areas, Exploratory research) involves over a dozen CW research scientists and planners to conduct interdisciplinary research on the dynamic interactions between people and natural ecosystems in urban settings in ways that will advance both fundamental and applied knowledge. The central question guiding the Chicago Wilderness ULTRA-Ex is: In a complex urban/metropolitan socio-ecological system, what are the synergies and tradeoffs between conserving biodiversity and providing ecosystem services to people?

Two of our principle objectives for this project are:

(1). To critically investigate connections between the biodiversity-recovery goals of the Green Infrastructure Vision and the delivery of ecosystem services to human communities throughout the Chicago region.

(2). Develop a multi-faceted, interactive, web-based Chicago ULTRA-Hub which is an interactive platform for managing data, communicating research findings to planners and the public, and collaborating and interacting with scientists and practitioners.

A2.4. Chicago Stew-MAP

Citizen-led environmental stewardship has proven to be critical for long-term, sustainable environmental management. There is a long history of stewardship in the Chicago region, but the current extent and distribution of this work is not known. Funded by the US Forest Service, and partnering with the Center for Neighborhood Technology and the Field Museum, Chicago Stew-MAP (Stewardship Mapping and Assessment Project) is the first effort of its kind to look at the "big picture" of stewardship in the CW region. The purpose is to better understand who is doing stewardship work, what they are doing and where, and how formal or informal the groups are. The goals of Chicago Stew-MAP are:

(1). Map sites and areas where stewardship is occurring.
(2). Help connect stewards with organizations or agencies that can help them meet their goals (for example, by providing funding or supplies).
(3). Show land managers, planners, and environmental professionals where the region's stewardship strengths and gaps are.