Arboretum 75th Anniversary Seminar

A galaxy of speakers addressed the future of restoration ecology

Photo by Claudia Lipke

The Arboretum's 75th Anniversary Seminar explored the history and future of restoration—both science and practice. Under the supervision of Joy Zedler, Botany 950 students traced the development of key ecological concepts through history. Under Paul Zedler's guidance, Environmental Studies 992 students brought their interdisciplinary approaches to bear on where the Arboretum could make its greatest contributions in the future. We also asked our guest speakers (featured below) to offer guidance on how restoration might meet the challenges we can expect as land use and climate continue to change over the next 75 years.

The future begins with conservation: Preserve what remains; Restore what is damaged.

Globally, The Nature Conservancy (TNC) has protected 119 million acres of land and 5,000 miles of river, while aspiring to work with others to ensure the effective conservation of places that represent every major biome. State Director **Mary Jean Huston** reported that Wisconsin TNC has protected 140,000 acres in 50 years but through ecoregional planning has identified 13 million acres as "areas of conservation importance." These lands make up a fourth of the state and represent a conservation challenge that explains

Mary Jean Huston
Director of the Wisconsin chapter of The Nature Conservancy (TNC)

why TNC partners with like-minded organizations, as well as governmental units.

To achieve conservation goals, TNC's Government Relations staff works to maintain a strong Stewardship Fund, which allows Wisconsin to purchase lands that are critical for conserving biodiversity (TNC's mission).

Setting aside land is one of many essential steps; considerable effort goes into planning before, and management afterward, in order to minimize threats to biodiversity. Field staff of this science-based and science-guided organization employ brush clearing, controlled burning, stream restoration and planting of native species to achieve conservation and restoration goals. They manage adaptively, using a four-step cycle called "conservation by design" (set goals, develop strategies, take action, measure results, and repeat).

Recently, TNC received a major land donation in the Mukwonago River watershed, conserved Military Ridge grasslands, and protected 65,000 acres of timberland in northern Wisconsin.

TNC promotes conservation via easements on working lands, land purchases, and public policy. Huston encouraged everyone to participate in this important conservation work by supporting organizations like TNC and by working to solve conservation challenges through their careers.

THE MEANING OF RESTORATION HAS CHANGED OVER TIME.

Curt Meine
Historian and biographer of Aldo Leopold

Curt Meine's retrospective on restoration began with a tribute to George Perkins Marsh, who in his 1864 classic work *Man and Nature* referred in general terms to the "restoration of disturbed harmonies." By the early 1900s, "restoration" was practiced through the reforestation efforts that followed the clear-cutting of white pine forests in the upper Great Lakes. Subsequently in the 1930s Aldo Leopold brought an integrated, ecology-based approach to the rehabilitation of degraded watersheds and the restoration of land health, e.g., in Coon Valley, Wisconsin. Working through the Dust Bowl years, Leopold combined scientific understanding (wildlife ecology, forestry) and management practice (e.g., planting trees and prairie) to develop restoration as a new branch of conservation. Restoration, in turn, informed Leopold's emerging land ethic—that it is everyone's responsibility to care for the land as "a community to which we belong."

After World War II, the environmental movement of an increasingly urban U.S. population supplanted the older conservation movement, and ecological restoration went into eclipse. When restoration re-emerged, the context was broader. Now, for example, Malpai Borderlands Group use fire to restore native grassland in the American Southwest, and Chicago Wilderness restores native ecosystems within a major metropolitan region. Over the last century, restoration emerged as both a science and a practice, but its ethical and philosophical dimensions of restoration can still be advanced in various social and cultural contexts to produce needed policies. Thus, Meine encouraged the Arboretum to continue its restoration science and practice while proposing bold new initiatives in restoration policy.

RESTORATION ECOLOGISTS USE DIVERSE APPROACHES TO SUSTAIN BIODIVERSITY AND FUNCTIONAL ECOSYSTEMS.

Exploring the past to predict future forest composition given changing climate

Paleoecology offers many tools that restorationists can use to set restoration targets, whether looking back over the past 4,000 years or forward to altered climate, land use and fire regimes.

Beginning with Wisconsin's northwestern sand plain, **Sara Hotchkiss** showed how quantifying pollen in deep cores, differentiating layers of wood versus grass charcoal, and assessing spruce budworm remains can reveal historical changes in assemblages of tree species. At 33 sites, her research group described patterns before and during the Medieval Warming Period, during the Little Ice Age, and since the Public Land Survey (PLS). By comparing abundances of tree pollen, Hotchkiss and her collaborators plotted community change by calculating similarities and comparing the magnitude of compositional shifts at multi-year intervals. The largest change followed the PLS and widespread clear-cutting. Hotchkiss identified assemblages that differ in dominance (e. g., jack pine,

Sara Hotchkiss
Professor, UW-Madison Department of Botany

red pine, white pine, oak-hickory), then compared their shifts over recent millennia in multiple sites. While noting the difficulty of assigning cause (e.g., to changes in temperature, rainfall or fire regimes), Hotchkiss asserted the need to understand long-term tendencies in order to predict the future. Hotchkiss's research is now expanding to more of northwestern Wisconsin, where climate-change effects are strongest, i.e., where winter and spring temperature maxima are increasing most and growing seasons are extending. Her aim is to use these paleoecological tools to complement those of vegetation and climate modelers (David Mladenoff and Dan Vimont) in order to forecast future forest composition with increasing precision (i.e., the 100-km^2 spatial scale).

Finding ways to control an invader

The invasive herbaceous plant garlic mustard *(Alliaria petiolata)* is difficult to control in Illinois savannas and woodlands. Studies of its biennial life cycle suggested to **Roger Anderson** and his students that early spring growing conditions are critical to its invasiveness. Because it emerges early and outgrows native understory plants when light is available and thrives after the deciduous overstory diminishes light, they tested seasonal light requirements. After establishing that shadecloth cages did not affect temperature, they caged individual plants in two wooded sites and compared garlic mustard growth given varying durations of light ambient. In both sites, plants exposed to the longest light period produced the most biomass. Early season shading appeared to slow growth more than late-season shading, but statistical analyses did not reveal clear differences. A second experiment varied time of hand-pulling second-year plants and identified an optimal time for garlic mustard removal. If second-year plants are not pulled early in the season but allowed to grow tall (prior to flowering), they will shade first-year seedlings and reduce the number of plants that survive to year 2. Because hand pulling is time consuming, this approach can reduce the total work load. Anderson concluded that restoration to control invasives and restore natives must be developed locally, i.e., approaches must be site-specific. Garlic mustard, like most invaders, must be treated as soon as it is noticed, because the methods available to control major invasions require broad-spectrum herbicides that kill all plants and potentially harm many animals.

An intensive approach to restoring prairie vegetation

Restoration outcomes depend in part on the initial conditions, but few have explored the effect of "year." **Jeb Barzen** and colleagues tested the effect of planting prairies, holding site conditions and seed mix constant and varying the year of establishment at the International Crane Foundation near Baraboo, Wisconsin. Between 1990 and 1996, his team planted five plots with 1,000 seeds/m^2 using 11 grass and 59 forb species, burned them annually, and assessed cover annually for up to 17 years. Each prairie outcome was unique, both in the dominant species and the cover of the most abundant species. Diversity (initially 60–95 species per site based on 0.25-m^2 samples along transects) decreased over the study period to 55–80 species, although the rate of change slowed over time. Changes were still occurring after 17 years. Thus, determining when restoration is finished (or when change has slowed) requires long-term monitoring. While causes of the different outcomes are uncertain, a

Roger C. Anderson
Distinguished University Professor of Ecology, Illinois State University, Normal

Jeb Barzen
Director of Field Ecology, International Crane Foundation.

single weather extreme could determine dominance for decades. For prairie restoration to have greater regional impacts on biodiversity, restorationists need to help landowners understand the need to restore land and become more willing to invest large areas in long-term projects that involve smaller, multiple plantings over time, instead of infrequent large plantings.

An extensive approach to restoring prairie vegetation

Prairie restoration is challenged by the small area of native sites that remain to provide native seeds, and the widespread use of cultivars that have been selected for high productivity. Thus, it is important to know whether seed source makes a difference to restoration of both the prairie community and its ecosystem functions. **Sara Baer's** ongoing field experiments support her hypotheses that cultivars affect belowground productivity, photosynthesis, aboveground productivity, diversity and more. Effects were more extensive for *Androgon gerardii* than for two other species she tested. Related reciprocal-transplant experiments aim to understand how natural genetic variability of *A. gerardii* relates to east-west gradients in precipitation, holding latitude constant. She predicts greater drought tolerance in Kansas than in Illinois.

Sara Baer
Asst. Professor, Southern Illinois University, Carbondale

Baer's extensive research uses strong science to improve the practice of restoration and restoration sites to test ecological theory. Her long-term studies of prairie restoration chronosequences indicate strong patterns of increasing root biomass, soil carbon, fungal growth, fungi:bacteria biomass, and the size of soil aggregates that sequester carbon, and they show that rates and patterns are affected by soil texture. Recovery is faster with clayey soils than for sand prairies. Even for the finer soil, however, her models predict it will take a century to recover natural levels of soil carbon. Long-term experiments that are replicated across soil types and precipitation gradients show great promise for unraveling the workings of community dynamics and ecosystem functions.

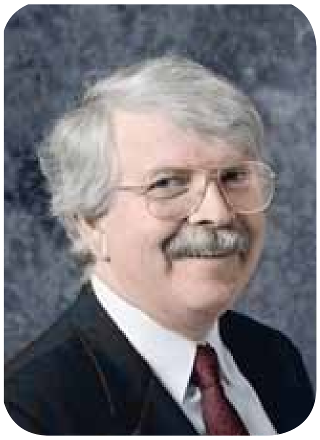
Using quantitative modeling in prairie restoration

Evan Weiher
Professor, UW-EauClaire

In an innovative test of factors that influence community assembly, **Evan Weiher** employed structural equation modeling to evaluate functional outcomes of experimental prairie plantings in a former agricultural field. His 4-ha experiment varied forb richness (holding graminoid richness constant) and disturbance (nitrogen addition and a fungicide to reduce mycorrhizal activity). A second innovation was his evaluation of plant attributes rather than species composition. The "deconstruction" of the community to a set of 4–5 explanatory variables (some being composites, such as "soil," represented several qualities) led to a robust model that expressed soil and light as having direct effect on plant trait diversity, while adding excess nitrogen or fungicide shifted the system toward the invasive bluegrass or quackgrass, respectively. Weiher tested the robustness of the model with 22 repetitions, of which 16 were similar to the result he presented. Likening these results with post-modernism, Weiher emphasized that the model is consistent with the data, but not necessary true. Because results are always influenced by local spatial and temporal variation, the plant attributes selected, and interactions between species in the community and their abiotic environment, ecological restorationists can follow a model in attempting to restore prairies but should not be surprised if such restoration efforts miss the target.

Consider diversity and adaptations

Restoring ecosystems requires understanding of the diversity and adaptations of species, as documented by **Tom Givnish** for several ecosystems.



Tom Givnish
Henry Allan Gleason Professor of Botany and Environmental Studies, UW-Madison

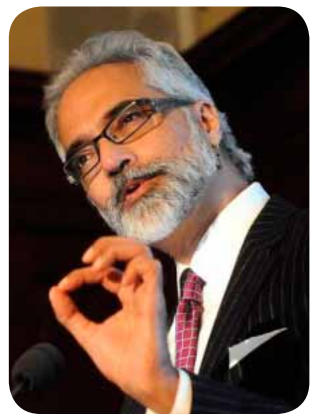
In wetlands, plant diversity is often associated with hetergeneous topography, and his new model (for Everglades tree islands) shows how biological feedbacks build and sustain the range of habitats that are occupied by floating aquatic plants, emergent graminoids, and trees. Also key are the birds that roost in the trees and deposit guano that enriches the soil of the tree islands. Restoration requires attention to more than historical water depths but to the water-flow regimes that drive the system.

In prairies, the traits of species that have declined in remnants along railroads and steep hillsides provide four cues for restoration: Conserve short-statured species, which cannot compete with taller species; small-seeded species (for which reestablishment is impaired in root-packed soils); and nitrogen-fixers (which do not thrive in unburned prairie remnants), and burn sites to reduce nitrogen levels.

In savannas, variations in light and soil support diverse vegetation and fire to sustain the patchiness. Diverse plant traits show spatial pattern, with more narrow-leaved plants in high light and sandier soil, and more broad-leaved plants in shade with richer soil. It is encouraging that 22 savanna remnants (42 ha total) still supported 27% of the Wisconsin native plant flora (507 species) a decade ago, but discouraging that savanna restoration is not organized to sustain that diversity. Givnish emphasized the need for a national savanna restoration effort, given this ecosystem's high diversity and historical loss of area (99.9%).

Plant traits might be better indicators of ecosystem functioning than species

The diversity of individual ecosystems has been described by counting species (species richness) and calculating diversity indices (e.g., evenness, H'), by assessing functional diversity (FD, which relies on groupings of species), and most recently by quantifying the functional traits without concern for their species identity or functional groups. In restoration and other conservation efforts, an index of ecosystem functioning could help practitioners determine when desired ecosystem services have developed.



Shahid Naeem
Professor, Columbia University

In search of an overall descriptive index of ecosystem function, **Shahid Naeem** explored a variety of approaches to quantify functional traits in pursuit of predictors of ecosystem services, such as the production of biomass. Using data on traits for the well-described vegetation at Rothamstead, England, he and his lab developed a mathematical model that yielded a new index, RIRDF, which performed as well as H' and FD, explaining over 30% of the variation in biomass. Surprisingly, species richness performed even better by explaining ~45% of the variation. What RIRDF allows that others indices do not, however, is a breakdown to the three vegetation traits, namely, requirements, impacts on the ecosystem, and responses to environmental change. Greater explanatory power might be possible with data on more functions of component species. Also, such approaches would have more utility if there were rapid assessment methods for quantifying functions. Until those become available, Naeem suggests that conservationists follow Leopold's advice to "keep all the parts" of ecosystems in order to retain their services and sustain human well-being (cf. the Millenium Assessment).

The new technology of geomatics aids restoration efforts

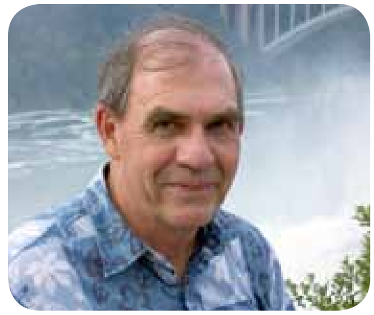
Geographic Information Systems (GIS) and Remote Sensing (RS) have many applications in restoration and more will be developed in the future.

Jonathan Chipman illustrated this message with three examples. First, he demonstrated the value of GIS for a student's (C. Little) ongoing analysis of plant attributes (growth, reproduction, and pollinators) in areas with and without metal contamination from mining operations. Point data on the ground became the basis for contour maps of plant attributes, revealing fine-scale patterns of spatial variation that might be missed in a non-spatial analysis. For RS, he described DNR's statewide mapping of the invasive reed canary grass (RCG), which was based on canopy spectral reflectance (RCG remains greener than other vegetation through September and October, i.e., its phenology trait). In addition, he showed how RS tools can assess lake water clarity (not to be confused with water quality, as there are different causes of low clarity). In each case, he reported that restorationists and others were eager to use GIS and RS results and products. A wealth of spatial and temporal information is being brought to bear on land management and restoration efforts. Future users need to consider the scope of information required, the type of sensor that is appropriate for the information, the type of analyses to be conducted and the budget available.

Jonathan Chipman
Director
Laboratory for Geographic Information Science, Dartmouth College

Novel approaches are needed to meet future restoration challenges

Novel approaches will be needed



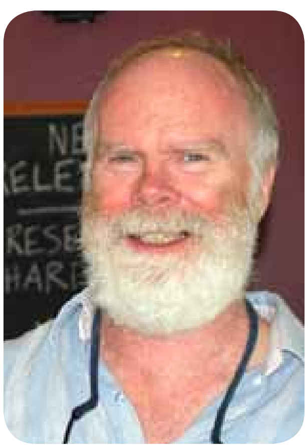
Jack Ewel
Emeritus Professor
University of Florida

Jack Ewel (*Emeritus Professor, University of Florida*) challenged ecologists to consider new approaches for restoration. For example, alien species are often avoided in restoration, but recent case studies indicate how they can play critical roles that complement native species. In the Florida Everglades, rock-plowed soils produced a Brazilian pepper forest after agricultural abandonment; a novel ecosystem supported the endangered panther; yet it was restored to sawgrass that provided inferior habitat for panthers. In Hawaii, an alien grass- and tree-fern- dominated site was churned up in order to reestablish an Acacia koa forest without first asking if the novel plant community would have developed into the desired forest given sufficient time. In another Hawaiian ecosystem that had been logged and kept bare by firewood collectors, the hillsides eroded and no native tree could deter firewood collection. An alien fig tree with poor quality wood was introduced; grew well and did not tempt local people to harvest the wood; instead it provided fruit, leading to a sustainable system that controlled erosion. These cases suggest the need to consider two critical questions in planning restoration: When should the existing state be “tweaked” versus replaced; and when should alien species or novel ecosystems be accommodated, rather than insisting on natives? Ewel suggests that restoration not be planned to mimic yesterday’s reference ecosystems, but for tomorrow’s novel environmental conditions, which will likely require novel assemblages of species. His conceptual model recommends that the more disturbed (harsh) the site and the fewer native features it retains, and the less complex the ecosystem, the more latitude there is for employing novel approaches.

The future might not have analogs in the past

Restoration ecologists have tended to focus on repeating the past, a strategy that does not prepare restored ecosystems for continually changing futures, according to **Richard Hobbs.** Not only is history difficult to know, it is constantly being rewritten and difficult to duplicate. The future will likely involve unprecedented conditions, uncharted territory, novel ecosystems or "no-analog" futures. Current problems in Wisconsin and elsewhere include invasive species, prairie succeeding to woody vegetation, urban sprawl, predators that attack people, use of fire near housing developments, and sustaining diversity of both species and genotypes.

Solutions are not easy to obtain, so restoration ecologists need to employ a battery of techniques such as identifying patterns, testing drivers, conducting experiments, and using many kinds of models. While no single approach can answer difficult questions, we can use the models to improve understanding overall. Hobbs addressed these problems with a consistent message, that ecologists need to be clear on objectives and then provide a suite of options by identifying alternatives with different opportunities and costs. The larger task may be to get people to agree on where to do what. Looking forward requires that restoration be viewed as a part of the larger field of "intervention ecology."



Richard Hobbs
Editor-in-Chief of
Restoration Ecology;
University of Western Australia

Adaptive approaches help reduce uncertainty

Joy Zedler
Professor of Botany and Aldo Leopold Chair in Restoration Ecology, UW-Madison

When there is uncertainty about how to achieve a specific restoration target, **Joy Zedler** recommends taking an adaptive approach to "learn while restoring." The approach is especially useful for large restoration projects with many unknowns. Four main steps are to (1) prioritize the unknowns that need to be known to restore the site; (2) design the project as sequential phases that involve spatial modules, often of increasing size as work progresses; (3), design one or more experiments for the first module; and (4) use the knowledge gained in earlier phases to design later experiments in subsequent modules. Critical to the process is having an oversight group that collects and uses information on experimental outcomes to decide on management actions and future experimentation. For the Arboretum, this group is the Adaptive Restoration Task Force, which involves the director, staff, faculty, and students. Examples at the Arboretum are attempts to eradicate reed canary grass in Curtis Prairie (three years of experimentation rejected a graminicide and justified a broad spectrum herbicide over multiple years), shrinking the boundary of reed canary grass in Lower Greene Prairie (a project involving ~90 UW Ecology students annually), restoring herbaceous vegetation in South Shore Fen (comparing canopy removal approaches), and using new stormwater facilities to test functional capacity of native wetland plants assembled by expected service (holding soil, infiltrating water, reducing invades) and planted at low- and high-diversity levels. Zedler's "Adaptive Restoration Lab" (Botany 670) allows students to learn the steps while developing much-needed plans for real-life clients.

Plant Ecology Seminar: Our restoration legacy

Tracing the history of six ecological concepts helped students in the Anniversary seminar recognize the roles our guest speakers (in bold, below) played in shaping Restoration Ecology. Students (in parentheses) addressed restoration targets (Sally Gallagher), succession (Karen Cardinal), assembly rules (Rachel Rodman), alternative states (Jim Doherty), heterogeneity (Erik Olson), and the land ethic (Brian Huberty), all of which help the Arboretum and its Adaptive Restoration Task Force address its land care responsibilities. The six concepts also help answer six key questions about restoration:

What motivates restoration? Aldo Leopold's land ethic drives restoration at the Arboretum and elsewhere. His ethic was developed as an inspiration to reduce overexploitation of land and minimize "wounds" to the landscape. For example, he sought to curtail farming and logging practices that caused soil erosion, gullying and loss of wildlife habitat. Leopold also led the way both for his family and for the Arboretum to restore degraded farmlands. At the Arboretum, William R. Jordan III embraced restoration and helped expand the practice as a means to advance ecology while learning how to recover native ecosystems. The land ethic continues to be promoted by the Arboretum and the Aldo Leopold Foundation, which has a new Legacy Center near Baraboo, Wisconsin.

What should we restore? The Arboretum's earliest "restoration target" was to re-create ecosystems that existed when Europeans settled Wisconsin; later, others, including **Richard Hobbs,** emphasized the need to consider targets as dynamic ecosystems and question which species and ecosystems are actually native. Still later, both Hobbs and **Jack Ewel** looked forward to times and places where native species and historically-occurring assemblages might not necessarily establish in novel restoration sites.

What approaches facilitate restoration? Providing "topographic heterogeneity" is one approach to restoring biodiversity, since both seedlings and adult plants, as well as animals, can segregate where resources are variable. The components of heterogeneity can vary both spatially and temporally, but the basic concept is directly applicable to restoration, as reviewed by Dan Larkin and co-authors in *Foundations of Restoration Ecology.* **Sara Baer** explored large-scale heterogeneity of restored prairies by comparing outcomes across soil gradients, holding latitude constant, and latitudinal gradients holding soils relative constant. The Arboretum's varied topography generates gradients of moisture, soil type, light, nutrients, and fire intensity that help create diverse environmental conditions for a wide diversity of plant species.

Will plantings persist? Once established, plant assemblages experience slow, gradual change toward some endpoint, and repetition of the sequence when a major disturbance occurs. Early in the history of ecology, Frederick Clements described the more orderly patterns of change as "succession." Currently, **Tom Givnish** is using the 50-year record (1955–2005) of tree density, occurrence and basal area in Noe Woods to show increased dominance by white and black oak, but no oak reproduction in the absence of fire, meaning that the site will eventually shift to dominance by other species. It is increasingly clear that successional changes are driven by both external and autogenic changes in an ecosystem, but it is still difficult to predict trajectories and outcomes of specific restoration sites.

Are there rules that govern species establishment? Ecologists have sought to identify "assembly rules" that explain shifts in species composition. However, decades of experience with restoration projects in USA and abroad have not yet produced a rule book. **Evan Weiher's** current research uses structural equation modeling in a continuing effort to simplify patterns, identify assembly rules, and predict patterns of change in restored prairies.

Is there more to restoration than manipulating succession? Yes, say many authors in a recent book co-edited by Hobbs and Katherine Suding. Succession is countered by the concept of "alternative states," which describes compositional shifts that resist restoration due to strong internal feedbacks. Invasive shrubs in Curtis Prairie are a potential example—once gray dogwood becomes dominant, the herbaceous cover that fuels fires declines, and subsequent fires are unable to control all the woody plants. Invasive reed canary grass and cattails are additional examples, as demonstrated by my students for Arboretum wetlands. Once the alternative state is reached (e.g., a monotype of an aggressive invader), restoration requires much stronger and far more persistent methods of control.

—Joy Zedler

Environmental Studies Seminar: Understanding the past helps the Arboretum move forward

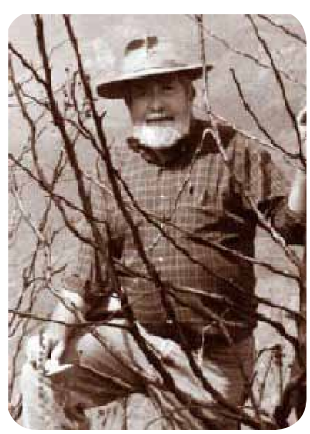
The public land survey (PLS) records of 1833 show the Arboretum area as having a large amount of marsh, and an Indian trail that crosses from Lake #3 (Monona) to the pond (Lake Wingra)—evidence of human use. There is no prairie indicated for this township. This supports other evidence that Curtis Prairie was not restored on prairie soil. Within the township, surveyors made special mention of the "sugar stand" (the maple forest in present day Maple Bluff). That this should be called out is evidence, as they say in their summary, that most of the trees they encountered were burr, white, and black oaks, with an understory of "oaks and grass" It is unlikely that the surveyors did not know the difference between broadleaf plants and grass, so this tells us that there was a lot of grass in addition to the trees. Also there could hardly be "oaks" as understory unless the woods were very open and frequently burned. It is not clear if these were "savannas" or just open frequently burned woods, or if these names mean different ecosystems.

The PLS notes for what is now the Grady Tract include a notation, "many deer and prairie wolves." If the land still supported wolves, it would not have been highly humanized (unless "prairie wolf" meant coyote). Taking this all together we have the picture of a landscape with clear signs of human activity, open oak dominated woodlands, marshes, and a reasonably complete fauna.

Historically, there were at least two choices for the Arboretum—traditional landscape architecture approach (exemplified by Frederick Law Olmstead) or a "wild" landscape (Thoreau). The Arboretum chose both paths. The civic visionaries had something more like a park in mind for the "Arboretum," and some of the University scientists shared this. Hence, part of the Arboretum is a traditional arboretum—a place where native and exotic species are cultivated in pleasing arrangements and where fabricated garden ornamentation is permissible. But another contingent felt that much of the land should be returned to a condition approximating the original state of the landscape—restored, we would say now. Since natural lands management is less expensive than intensive gardening, expediency supported the Thoreauian view. Beginning as an academic dream to get back some of what had been lost, the idea of restoration came to be a major theme in applied ecology. But as we look to the future, is our objective to have any kind of wildness that is sustainable, or will we stick to the idea of reconstructing the 1830's landscape to the degree possible? Given exotic species invasions and the novel groupings of species that have come into being on our lands, is reconstruction even possible?

Like any organization, opinions of those concerned about the Arboretum differ, but in balance we remain committed to the original idea. How badly astray can this lead us? If we proceed with sound science and an adaptive approach (specifically, adaptive restoration) then we will accumulate valuable understanding even if we fail to achieve the "wildness" target. And if native ecosystems are restored, then the Arboretum will continue to be invaluable as an area that can be compared to others that lose the battle against exotics and new patterns of disturbance.

—Paul Zedler



Paul Zedler
Professor of Environmental Studies, UW-Madison, Senior Scientist, UW Arboretum