Arboretum Leaflets
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RESTORATION TARGETS ARE CHANGING

Early ideas

As implied by the word “restoration,” early targets were about replacing what was lost. Environmental historian Curtis Meine suggests that George Perkins Marsh (1864: *Man and Nature*) was the first to use the term *restoration* in an ecological context. Marsh referred to the “restoration of disturbed harmonies” and advocated rehabilitation of damaged landscapes. None of these terms was defined in detail, but some of the data that would later provide more specific targets was already being gathered by land surveyors, who were painstakingly recording the composition of vegetation across the North American frontier. In 1850, for example, surveyors sampled the 100-square-mile grid that intercepted central Wisconsin’s Buena Vista Marsh, making it possible to reconstruct its pre-settlement vegetation (Figure 1). What is now a mosaic of sandy agricultural land and prairie-chicken reserves was once a tamarack swamp surrounded by oak barrens.

Early records were often used to depict the “pre-European settlement” state of vegetation (often referred to as “original vegetation”), aided by early descriptions such as those by Weaver and Clements (1929), Leopold’s 1934 speech, and Arboretum records. The historical plant community “state” was a widely-used restoration target that could be both quantitative and quite specific. Specific targets, however, are easily missed (Figure 2).

While specific targets might not have been achieved, early restoration gave rise to *ecological restoration* (the practice of aiming for a target), *restoration ecology* (the testing of hypotheses to understand how things work) and *adaptive restoration* (learning while restoring, by testing alternative approaches and expanding the use of effective tools). These were not small achievements. Nor were they late in coming. In various ways, it can be argued that (1) both states and services have been used as targets from the earliest days of ecological restoration and that (2) both trials and experiments were used to achieve those goals from the very beginning. First, we know that Aldo Leopold (1934) called for the Arboretum to provide examples of pre-European plant communities, but he also called for their ability to support research and education (now considered ecosystem services). Second, we know that Norman Fassett and his then-graduate student John Thomson initiated experimental approaches (comparing seeding, using marsh hay, transplanting sod blocks) to convert a horse pasture to prairie vegetation beginning in 1935!

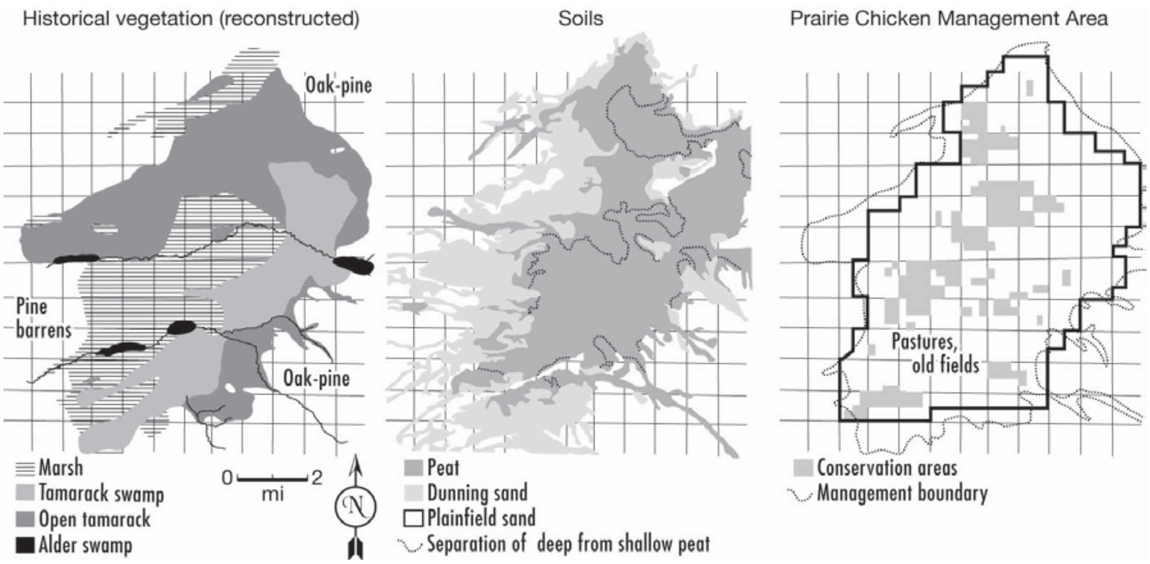
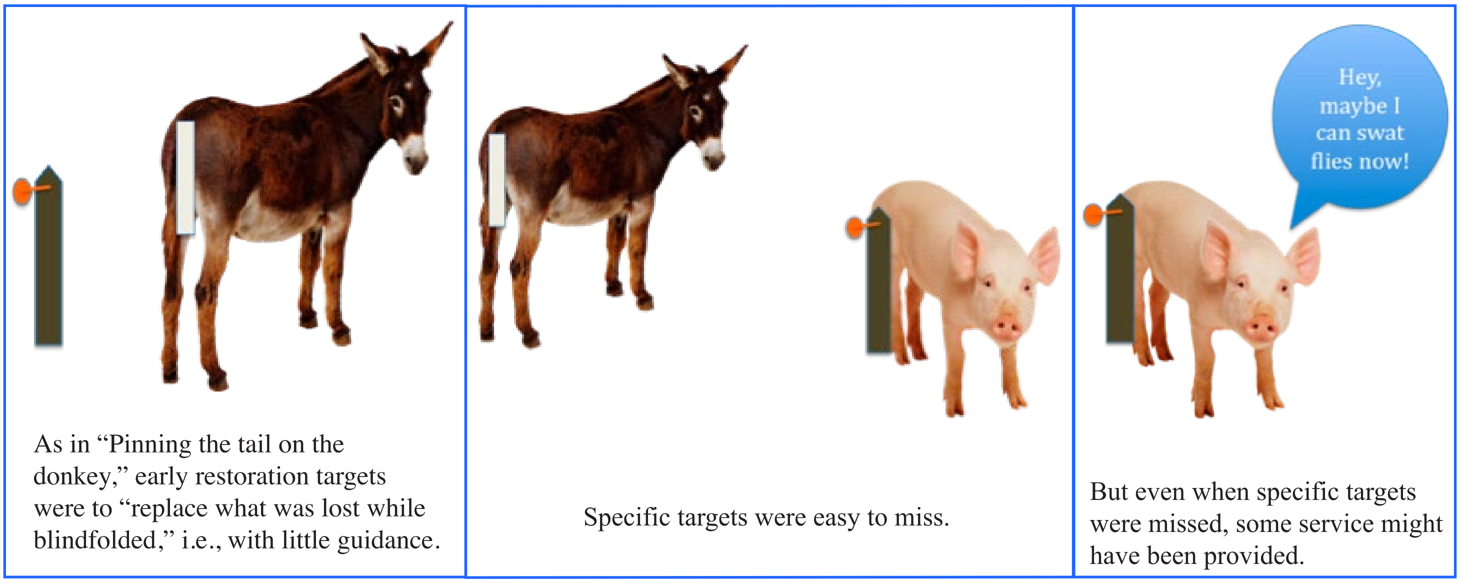


Figure 1. Surveyor records and old soils maps allow interpreters to characterize historical “states.” But if critical factors (e.g., peat) have been lost (to drainage and fires), then the historical state is not fully restorable. Some new conservation use is more achievable (e.g., management for prairie chickens by mowing “booming grounds” in pastures and fields that were once used to grow bluegrass seed; Zedler 1966).



As in “Pinning the tail on the donkey,” early restoration targets were to “replace what was lost while blindfolded,” i.e., with little guidance.

Specific targets were easy to miss.

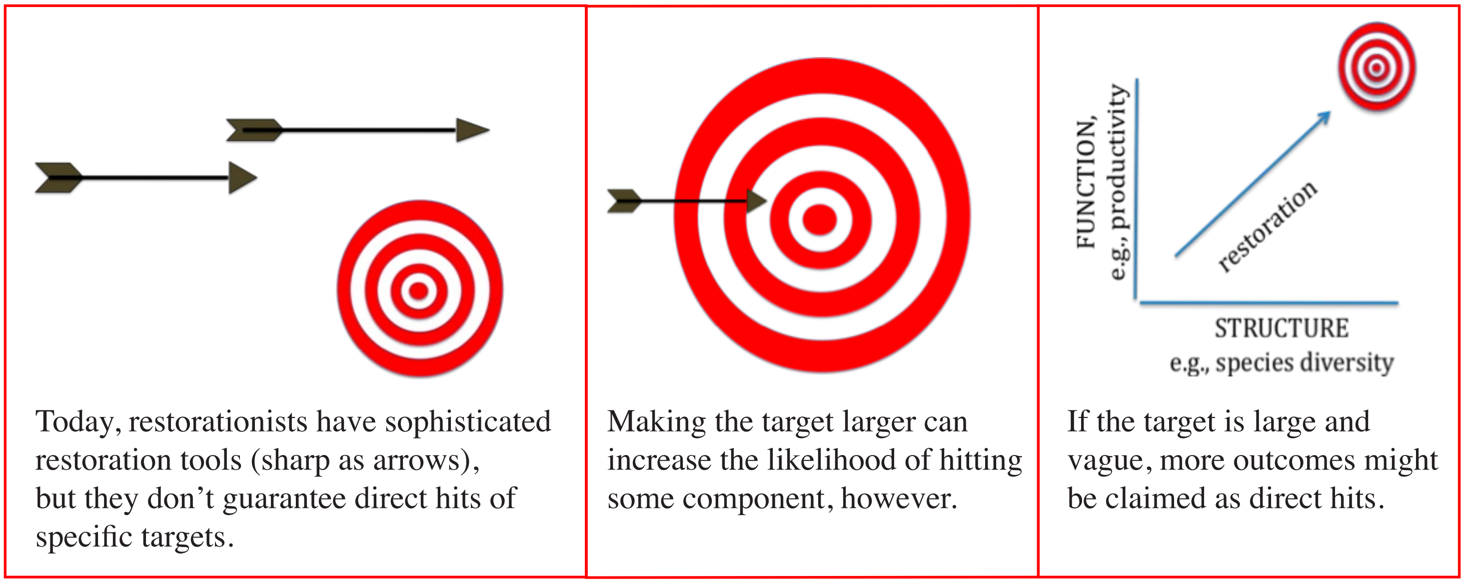
But even when specific targets were missed, some service might have been provided.

Figure 2. Early in the history of ecological restoration, it was common to imagine that the clock could be turned back to an earlier time. [Animal photos from Microsoft “Clip Art.”]

Current activities

In a 1997 article in *Science,* Dobson et al. described the ecological restoration as having a “powerful suite of tools” that offer great hope in regaining lost ecosystem functions and values. Any increasing ability to hit targets, however, might depend more on the size and number of targets (Figure 3) and on subjective judgment (Zedler 2007). In another recent article on “hope,” Jones and Schmitz (2009) quantified ecosystem recovery based on the judgments of authors whose work they reviewed (240 papers), but Jones and Schmitz did not include the information that would be needed to critique those judgments or to determine if the literature base is balanced in reporting recovered and non-recovered ecosystems. Indeed, the literature appears to underrepresent projects that do not meet their objectives. To counter such bias, the journal *Restoration Ecology* recently established a new section on “Setbacks and surprises” to provide an outlet for negative results.

The possibility that ecosystem function is dependent on species diversity has stimulated hundreds of experimental studies, with mixed results. When experimental units are continually weeded, the relationship is often positive (Figure 3). In contrast, however, several attempts to identify positive correlations in restoration sites either show a negative relationship (Jelinsk et al. 2010) or an early positive relationship that shifts to negative or no correlation (Doherty, Callaway and Zedler *in review*). Shifts toward negative relationships make sense, given that a few aggressive species often become dominant, reducing overall diversity at the small (0.25–1.00 m^2) scale.



Today, restorationists have sophisticated restoration tools (sharp as arrows), but they don’t guarantee direct hits of specific targets.

Making the target larger can increase the likelihood of hitting some component, however.

If the target is large and vague, more outcomes might be claimed as direct hits.

Figure 3. Larger and more vague targets are easier to hit than specific quantitative targets. The early idea of restoration as the simultaneous recovery of structure and function (Bradshaw 1987) was reprinted often but never supported by data. Productivity can be negatively related or unrelated to plant diversity, as can many other ecosystem attributes (Zedler and Lindig-Cisneros 2001). [Bradshaw’s 1987 graph modified by J. Zedler.]

Diverse restoration sites can, however, increase functions under two circumstances: (1) Diverse planting mixes will be more likely to include a "super species" than species-poor mixes. I define super species as providing multiple functions and/or high levels of at least one function. An example of a multi-functional species is *Carex stricta,* the tussock sedge, which facilitates the growth of other species (Peach and Zedler 2007; Frieswyk et al. 2008) and also stores substantial carbon in its tussocks (Lawrence and Zedler *in review*). (2) Diverse plantings can be designed to exhibit complementarity, i.e., providing greater/more functions via niche or resource segregation. At the Arboretum, collaborators and I are testing low- and high-diversity "designed assemblages" for their ability to provide three ecosystem services—erosion control, infiltration, and invasion resistance—for use in stormwater-treatment facilities. Nine species that have potential for reducing erosion ("soil holders"), nine that should create deep root channels ("infiltrators"), and nine that might reduce invaders by casting heavy shade ("competitors") were planted in November 2009 at two levels of diversity (trios @ 1 species per proposed functional group and nonets @ 3 species per group). We expect the nonets to provide more functions at higher levels than trios or solos, and this summer we will begin determining which, if any, designed assemblages provide the services that we have targeted for stormwater treatment.

A larger, less specific target should be easier to hit, but restoration should also benefit from a larger range of approaches to achieving goals. For example, recognizing that some kinds of degradation are difficult to reverse (often termed "alternative states") can focus efforts on identifying targets and breaking feedbacks, as suggested for sedge meadows that convert to an invasive grass monotype (Zedler 2009). Adaptive restoration (phased experimentation) is especially promising at the Arboretum, where both restoration and research are core components of our mission. And extending the deadline for hitting a target can help ensure desired outcomes.

Targets are now broad and varied for wetlands (see Box 1), for concerning functions, multiple targets, regulation of processes, ecosystem services, and watershed planning. For ecosystems in general, Whisenant (1999) focused his book on processes and landscape-scale approaches to restoration, and Lubchenco et al. (2001) called for more restoration research to understand processes that underlie sustainability. Meanwhile, the Society of Ecological Restoration broadened its 1990 definition of establishing a "historic ecosystem" to the more general aim in 2002 to "assist ecosystem recovery." Choi (2004) reinforced the need to rehabilitate functions. And the Millennium Ecosystem Assessment (2005) gave the world a strong message that we should restore ecosystem services and biodiversity to sustain human well-being.

The target of achieving full recovery quickly was addressed recently by Jones and Schmitz (2009), who selected 240 studies from a global review of publications from 1910–2008 and found that about a third met all their target, and 173 projects met at least one target in an recovery time of < 42 yr (typically < 10 yr). Two key concerns about this work are that (1) Jones and Schmitz relied on the many authors' opinions that targets were met, which introduces variable and subjective judgments, and (2) the conclusions are based on an assumption that the literature is unbiased in its reporting of projects that do and do not meet targets. A limited review of two journals (Zedler 2007) found the word "success" in 116 papers, while only 10 used the word "failure." Our 3-year study that did not determine how best to control an invasive grass (Healy and Zedler 2010) was among the first "Setbacks and Surprises" published by *Restoration Ecology*.

Box 1.

- Evidence for broad targets within wetland restoration comes from a variety of initiatives and writings over the past three decades. The 1973–5 Clean Water Act was based on important wetland functions, especially water quality improvement, and the 1988 report from the Conservation Foundation reinforced this in their call for no net loss of wetlands and function, which was then endorsed by Presidents G.H.W. Bush, W. Clinton, and G.W. Bush. Salt marsh work (e.g., Zedler 1993) was among the first to show showed that mitigation for damages to endangered species habitat did not replace the target function (bird nesting), despite revegetation.
- Soon thereafter, Pickett and Parker (1994) emphasized the dynamic nature of ecosystems, which makes static targets unrealistic, and Wyant et al. (1995) suggested that we consider multiple targets. And in 1997, Ehrenfeld and Toth recommended that the regulation of processes would be an appropriate target. An emphasis on valued processes (increasingly called ecosystem services) became urgent when Costanza et al. (1997) calculated the dollar value of annually renewable ecosystem services to be $33 trillion/yr, and various calculations of the percentage provided by wetlands indicated their disproportionate contribution (up to $13 trillion/yr, depending on how broadly "wetland" is defined).
- In 2001, a National Research Council Committee reinforced the policy for no net loss of area and function of wetlands and called for watershed plans that would indicate priorities for conservation (to avoid significant filling of wetlands), or minimization if impacts could not be avoided, and only if impacts could not be minimized would damages be permitted along with compensatory mitigation to sustain both acreage and function. Seven years later, the US Environmental Protection Agency and the US Army Corps of Engineers endorsed NRC's (2001) call for watershed planning, but no agency or interagency group was charged with developing such plans, and the regulatory guidance only required that such plans be used if they existed.
- Recent efforts (Bernthal and Hatch 2007; R. Glaser, US Army Corps of Engineers, pers. comm. 2010) and a state-wide strategy (Hruby et al. 2009) are notable efforts to become strategic in restoring wetland acreage and function. Finally, in 2010, watershed planning at a national scale was addressed by The Nature Conservancy and the Environmental Law Institute, who obtained funding from the Joyce Foundation to establish a model watershed planning effort in Wisconsin and another in Tennessee.

Still to come

Forward-looking ecologists have suggested many innovative targets for future restoration projects, ranging from using alien species to genetically modifying plants (Box 2). Some of these are well-reasoned, while others seem to rely on unrealistic assumptions. Using non-native fig trees made sense for a woodland restoration where local people were prone to harvest plantings for firewood. Because people wanted to keep the fig trees to produce fruits, they also inadvertently were slowing soil erosion on a steep slope. Likewise, extending time scales for achieving targets makes sense when the dominant tree lives to 300 years. In our stormwater-treatment research, we employ both novel assemblages and adaptive approaches to achieve complementarity among species planted, as a test of ways to increase ecosystem services. For the remaining suggestions, however, it may be unrealistic to assume that climate will change enough to eradicate current invasive species and unrealistic to expect that our knowledge of the genetically determined traits of species will be sufficient to modify genotypes for use in future restoration work. I hope I am wrong.

Box 2
Recent suggestions that speak to future restoration targets.

- Adaptive restoration: "Learning while restoring" (Zedler 1997, Zedler and Callaway 2003), practiced by the Arboretum Adaptive Restoration Task Force.
- Consider non-native species when benefits outweigh problems (Ewel and Putz 2004).
- Extend the time scale as far as 300 years to achieve old-growth woodland (Kirkman et al. 2007), e.g., gradually converting an undesired slash pine plantation to a sustainable longleaf pine woodland by keeping a decreasing number of tall slash pines as an overstory that drops sufficient pine needles to fuel fires that then regenerate the native wiregrass understory and foster longleaf pine establishment and growth.
- If site resists restoration, identify thresholds and feedbacks as in alternative state models (Suding et al. 2004).
- For novel conditions, use novel assemblages (no-analog communities; Williams and Jackson 2007; Seastedt et al. 2008)
- Include climate change in restoration planning (Harris et al. 2006).
- Transformative restoration: Some weeds will succumb to climate change (Bradley et al. 2009).
- Manipulate genetics: "assist evolution;" help plants survive future stressors (Jones and Monaco 2009).

Conclusion

Targets for specific states and services are often missed, but if the vision is for full recovery quickly, to date, the only claim for such an outcome is based on opinions and broad, vague targets. Such judgments may serve the purpose to offering "hope," but the role of science is to provide objective evaluations. I recommend that restoration scientists urge practitioners to clarify targets and consider longer time scales for achieving restoration goals. Scientists can complement practitioners' efforts by promoting adaptive restoration and conducting research that leads to unbiased assessments.

References

The references cited above are on-line as "Leaflet 21 Supplement: References for Leaflet 21."

This comparison of early ideas, current activities, and future targets by Joy Zedler was the plenary talk at the Midwest-Great Lakes Chapter of the Society for Ecological Restoration on April 9, 2010, at their second annual conference at the UW-Madison Arboretum. Thanks to SER-MGL for the opportunity to formulate these thoughts.

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