Driftless Prairies: Native Ecosystems

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- Home
    - Our Journey
    - Citizen Science
    - Driftless Area History
- “50 Ways” to Manage
- Tools & Techniques
- Research and Science
- Bio Inventory
- Blog
- E-mail Us

Reversing Reed canarygrass Invasions Requires a Multiple-method Systems Approach

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Background

Since its first appearance in the journal *New England Farmer* in 1834, reed canarygrass (RCG) has been a topic of 913 published studies from 311different peer-reviewed journals in ten languages, a compendium totaling more than 9,400 printed pages. Despite this large pool of information available to researchers and land managers, RCG is still considered one of the most problematic invasive species to tackle, and eradication is generally considered an unrealistic management goal even at local scales. The gap in restoration ecology between experimental research and experiential management is partly to blame for this mindset. For instance, we know from management experience that reversing a RCG invasion is possible and has even become a matter of routine but it requires 5 – 7 consecutive growing seasons worth of management effort. In contrast, the average length of time spent conducting an experimental eradication study is two growing seasons, after which the researchers generally conclude control cannot be achieved or a tested method is completely ineffective. These hasty generalizations are usually based on the results of short-term, single-site experiments often conducted in artificial environments (such as greenhouses and campus gardens) and have given rise to the widespread and misguided belief that current methods and restoration approaches are inadequate to address the RCG problem. Typically, such studies mention in their concluding paragraphs that “additional research is needed” before we can successfully confront RCG invasions. *Really???* How much more research is needed? Fortunately, we already have an extremely detailed profile of this species, including plenty of information to assist practitioners in reversing invasions. In this essay I will elaborate on how a multiple-method systems approach is key to making RCG eradication a matter of routine (and affordable) management.

What is a Systems Approach?

A prevalent viewpoint in invasive species ecology is that effective long-term control is simply a matter of finding the ideal herbicide formulation, application rate, and/or application timing window. The literature is replete with examples of experiments designed to find the ‘magic bullet treatment’, a quick, low-cost, and easy answer to RCG eradication. Yet, experience has taught us you cannot simply spray RCG away, no matter what herbicide or timing window you employ. The magic bullet strategy is based on **community structure**, which represents a *snapshot of ecological condition and species composition at a given point in time*, and focuses on single-method corrective measures (usually herbicide application) without regard to rectifying the underlying problems that predispose sites to invasions in the first place.

In contrast, the systems approach is process-oriented and based on **community dynamics**, a branch of ecology concerned with *how and why community condition and species composition changeover time*. Restoration within the context of a systems approach is a two-step process: Assessing and modifying site-specific variables making a site vulnerable to invasion (e.g., fire suppression, hydrological disturbances and alterations, sedimentation) along with feedback cycles that reinforce the invasion (e.g., litter accumulation and nutrient inputs) is the first step. The second is to utilize multiple suppression and revegetation methods properly applied, timed, and sequenced to simultaneously exploit the invader’s weaknesses (RCG has several) while drawing out native species’ strengths. The systems approach is sometimes called integrated vegetation management.

Community Dynamics as a Framework for Restoration

There are two schools of thought regarding community dynamics in the context of restoration. The traditional succession model predicts that community degradation occurs in a linear stepwise manner, with the invasive species gradually replacing the existing vegetation community. Restoration within the succession framework is the reverse of degradation; the invasive species is gradually forced out and replaced by native species until the system once again resembles its undisturbed remnant condition. Although this makes intuitive sense, several decades’ worth of restoration experience has revealed that restoration is seldom straightforward in practice. This is because the succession model doesn’t account for the intrinsic complexity displayed by natural systems. Practitioners are in need of a restoration framework that recognizes complexity yetis tangible enough to be of practical use.

While examining relationships between species-abundance patterns of grassland birds along a gradient of RCG abundance, Annen et al. (2008) determined RCG invasions conform more closely to the predictions of an alternative states model of community dynamics. The alternative states viewpoint predicts degradation occurs gradually until a critical mass (the **degradation threshold)** is reached, after which system collapse progresses at an accelerated rate relative to an ecological timeframe. Consider a degraded oak savanna invaded by buckthorn in the absence of fire. As buckthorn increases in density, there is a point beyond which simply returning fire to the system is adequate to reverse the invasion and return the savanna to an undisturbed state; this point is the degradation threshold. Restoration of post-threshold communities becomes increasingly more difficult and expensive because new internal processes set in motion by the presence of the invasive species alter community dynamics in such a way to reinforce the invaded state. Restoration within the context of the alternative states framework involves recognizing and manipulating system variables and feedback loops that contribute to and reinforce invasions in order to push the system over its **recovery threshold**. Beyond the recovery threshold, the practitioner’s job gets much easier and less expensive because the system acts to heal itself at an accelerated rate.

Elements of System Collapse

To illustrate how to use a systems approach to reverse a RCG invasion, we will review a case study of a how a RCG invasion pushed a remnant sedge meadow into a degraded RCG-dominated alternative state, as documented in Annen (2011) and summarized in Figure 1.

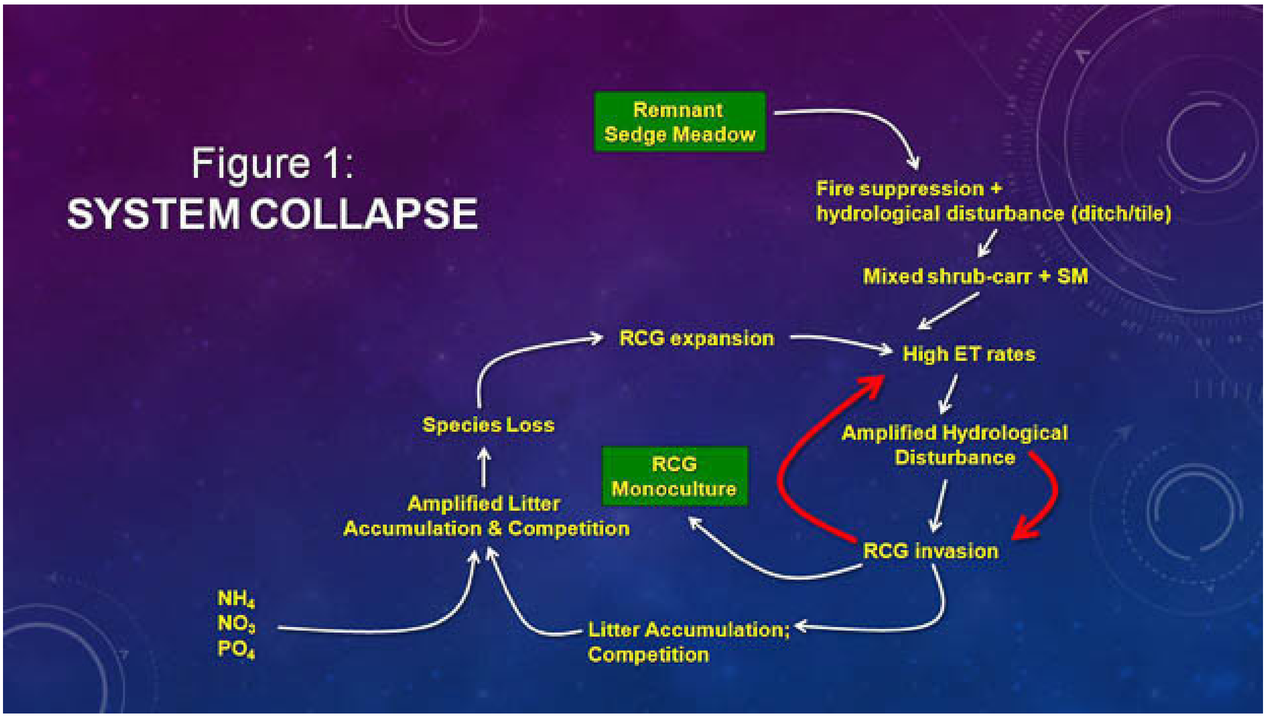


Figure 1:
SYSTEM COLLAPSE

Concept maps of system variables and feedback cycles involved in system collapse

Later in this essay we will see how understanding the dynamic processes and feedback cycles operating in RCG invasions are critical to designing effective reversal strategies. Although natural systems are complex and every invasion is unique, there are numerous commonalities in how a RCG invasion occurs and how a system responds to the invasion; this illustration can be applied to an array of invasion scenarios with only minor adjustments.

We begin with a high-quality, remnant-condition southern sedge meadow, similar to those described in Curtis (1959). Historically, southern sedge meadows experienced fire at a similar interval as wet tallgrass prairie (Kost and Steven 2000), which maintained their open character by favoring herbaceous vegetation over shrubs and trees. More importantly, fires maintained species richness and diversity by removing accumulated litter and excess nutrients, preventing clonal matrix sedges from becoming dominant. Widespread fire suppression coincided with the arrival of European settlers, leading to encroachment of many southern sedge meadows by fire-intolerant shrub-carr species (initially native willows, box elder, and dogwood and later honeysuckle and buckthorn). Conversion of the sedge meadow into a shrub-carr community had an indirect consequence: Shrub-carr species (especially willows) have high evapotranspiration (ET) rates and their presence lowered water tables, setting up a hydrological disturbance. This disturbance was intensified in the 1940’s when a drainage ditch and tile system were installed in a portion of the sedge meadow and the wet-mesic prairie that buffered itto drain the site for agriculture. Artificial draining augmented and intensified the existing hydrological disturbance and further predisposed the sedge meadow to invasion. The site experienced its first decrease in species richness as those herbaceous native species intolerant of lower water levels were extirpated, leaving small gaps in the herbaceous canopy and exposing empty niche space. Some of these canopy gaps were closed by the existing native species pool, some by expansion of shrub-carr species, and some by RCG. Other than initially delivering RCG germplasm to a site, seed rain is probably not an important factor in the expansion of RCG after establishment. RCG seeds have low viability and limited longevity in the seed bank. In well-established monotypic stands, only about 15% of culms develop a panicle in a given year (Evans and Ely 1941). Once established, a RCG clone spreads vegetatively through prolific rhizome growth. Clonal species normally expand by either a phalanx strategy, characterized by emergence of new tillers at a short distance from the parent clone, or by a guerilla strategy, where new tillers emerge in canopy gaps at longer distances from the parent clone. RCG is somewhat unique among clonal plants in that it can utilize both the phalanx and guerilla strategies for lateral spread.

Similar to shrub-carr species, RCG also exhibits high ET rates (Schilling & Kiniry, 2007), and its contribution to existing hydrological disturbances increased as it increased in abundance. A feedback loop emerged as water table levels dropped, leading to additional losses of native species and further expansion of shrub-carr and RCG into the resulting canopy gaps, in turn fostering additional water loss from the system (See Figure 1). Meanwhile, in the continued absence of wildfire, a dense mat of RCG litter began to accumulate, which had a mulching effect on native species near RCG clones, facilitating native species suppression and RCG expansion. As RCG expanded, it produced higher amounts of litter, furthering the mulching effect on native species and leading to further expansion. Thus, a **RCG-litter feedback loop** also developed in this system, leading to additional species loss (Zedler 2009). Curtis (1959:641) reported RCG was present in eleven different community types in Wisconsin, with maximum frequency in shrub-carr, lending support to this invasion scenario and highlighting the importance of fire dynamics in RCG invasions.

Crop production in the adjacent landscape also contributed to this invasion by increasing nutrient inputs. RCG is a strong competitor for light, but a weak competitor for nutrients; when excess nutrients entered this system, the balance of competition shifted toward RCG expansion. Nutrient additions also acted to amplify the RCG-litter feedback because luxury consumption by RCG increased its aboveground biomass production, accelerating litter accumulation and its mulching effect. At some point, RCG density reached a critical limit, after which litter accumulation began to rapidly displace not only the weaker competitors and rarefraction species, but also the common, subdominant, and eventually the dominant matrix species as the system sank further into collapse. The central point in this scenario is when RCG abundance reached a critical density, new feedback loops that internally reinforced the invasion emerged in the system, favoring RCG expansion with concurrent loss of native species.

Applying the Multi-method Systems Approach to an Invasion

Once the underlying drivers of RCG invasions are understood, it becomes evident that negative feedbacks that reinforce invasions need to be disrupted if any attempts at reversal are to be successful.

Step 1: Determine if the invasion is reversible and the site is in recoverable condition.

Given unlimited resources, all sites can theoretically be recovered, but practical considerations restrict the number of sites where RCG invasions can be reversed. Put simply, recoverable sites are in a condition below the degradation threshold. Although researchers have yet to empirically pinpoint threshold values, practical experience gives us some easy-to-follow guidelines for identifying recoverable sites

(Annen et al. 2008). These include sites where RCG is intermixed with well-established native species and sites where native propagule banks have managed to persist in the face of degradation. If you are uncertain if a site is in the latter condition, burn the site and then observe if native sedges and/or forbs re-emerge once accumulated litter has been removed. Many sites dominated by RCG respond to litter removal with substantial increases in species richness, indicating they are actually in recoverable condition despite their outward appearance. Restoring sites where well-established RCG dominates both the standing crop and propagule bank is possible, but cost-prohibitive and not always successful.

Step 2: Perform a site condition assessment and identify disturbances and feedback cycles triggering and reinforcing the invasion.

A pre-treatment site assessment provides the practitioner with valuable information to help guide restoration planning, particularly in regard to identifying the presence of factors and processes that contribute to RCG invasions. Condition assessment also permits the experienced practitioner to predict how an invaded site will respond to management.

System and forcing variables

System variables are the factors and processes responsible for a system's condition. Hydrological cycles, nutrient status, and litter depth are examples of important system variables that influence the trajectory a vegetation community will follow through ecological time. Disturbance occurs when system variables are modified in a way that results in a transition from an undisturbed (remnant) condition to an alternative (invaded) condition. For example, nutrient enrichment alters competition outcomes, leading to changes in species composition. **Forcing variables** are parameters that, when altered, either reinforce a system condition or force the system into a new condition. Periodic burning is a familiar example of a forcing variable; fire forces a system to remain in an open condition characterized by a lack of fire-intolerant trees and shrubs; in the absence of fire, a site is forced into a trajectory toward a closed-canopy wooded community. Management can also be thought of as a forcing variable because its aim is to push a system toward a particular condition.

A condition assessment should answer the following questions: Are indicators of hydrological modification (ditches, drain tiles, culverts) present? Is it possible to correct or modify these disturbances without affecting adjacent properties? What is the composition and relative abundance of vegetation present? Are silt deposits present on vegetation or have sedge tussocks been buried by soil deposits? How deep is the litter layer? Has the site experienced fire recently? What is the density and species composition of the shrub layer? Consider collecting soil samples and having them analyzed for NH_4-N, NO_3-N, and available PO_4.Nitrogen and phosphorus inputs from non-point sources are strongly correlated with RCG dominance. RCG is a poor competitor for nutrients and increasing nutrient availability tips the balance of competition in RCG’s favor.

RCG has a high degree of phenotypic plasticity (it can adjust its growth and development patterns in response to its environment) and readily adapts to growing conditions that drive off other species, such as flashy hydroperiods typical of stormwater-connected wetlands and artificial drainage, sedimentation, and nutrient inputs associated with agricultural production. The present ubiquity of RCG in the landscape results from the interaction of its life history traits with anthropogenic land-use patterns (particularly agriculture and urban expansion); these interactions impact system variables, and if they are strong enough can force the system into a RCG-dominated condition.

Whenever possible, primary and secondary hydrological disturbances, sedimentation, and nutrient inputs should be corrected (or at least modified) and feedbacks should be uncoupled prior to implementing treatments aimed at reducing RCG abundance. These actions are of critical importance, but are not always possible for a variety of monetary and legal reasons (e.g., removal of a culvert could risk flood damage to residential properties).

Step 3: Disrupt feedback cycles and reintroduce fire to the system.

As already discussed, litter accumulation is a primary feedback operating in systems dominated by RCG. Nutrient inputs into natural areas, common in agricultural landscapes, amplify this feedback by increasing aboveground biomass production and accelerating litter accumulation. We have also seen how conversion to shrub-carr creates a secondary hydrological disturbance that facilitates RCG expansion. These feedbacks can readily be uncoupled at relatively minimal cost with fire management.

Use of fire in RCG management is an example of how the gap between experimental ecology and management practice has misguided restoration efforts. Experiments show that burns are not directly lethal to RCG (even during peak growth), leading researchers to conclude that burns are an ineffective suppression method. Quite the opposite, burning is an essential accessory treatment because RCG invasions are litter-driven. In addition to removing accumulated litter and preventing conversion of herbaceous wetlands into shrub-carr, burning removes nutrients from the system; 15 – 90% of N (depending on species and time of year) and up to 80% of available P is stored in senescent aboveground litter. Repeated spring burning of the RCG area facilitates invasion reversal by removing nutrients and altering competition trajectories, since sedges are stronger competitors for nutrients than RCG. Gradual nutrient removal by haying or burning is termed **nutrient mining**, and Annen (2011) reported a

36% reduction of soil available P in a sedge meadow following three prescribed burn events. Initially, you will want to burn the RCG areas annually until the RCG cover declines to ≈10%. Litter removal will initially increase RCG seedling density, but since seedlings are not fully established they are particularly vulnerable to herbicide applications, allowing you to purge the RCG seed bank. RCG seeds remain viable for only a couple of years in saturated soils and you can expect few additional seedlings to emerge after the first couple of burn events. Importantly, since you will sometimes be burning wet sites, don’t be overly concerned if you are not able to completely burn a site; incomplete burns are more effective at facilitating RCG reversals than not burning at all. Likewise, since the aim of using burning as an accessory treatment for RCG reversal is litter removal, a burn can be carried out at any time of year when conditions allow.

Step 4: Modify system and forcing variables.

Step 4a: Correct or modify primary hydrological disturbances. Cost share through government agencies (e.g., waterfowl stamp programs) and nonprofit organizations (e.g. Ducks Unlimited) is sometimes available for complete or partial hydrological restoration projects, such as removal of drain tiles, filling drainage ditches, or installing weir structures. If hydrological restoration is not possible or affordable, opt for installing water-level control devices to provide you with some control over site hydrology. It is still possible to reverse a RCG invasion without restoring hydrology, but doing so requires more effort because restoring historical conditions promotes native species recruitment and establishment.

Step 4b: Correct secondary hydrological disturbances. Beyond a threshold density, shrub encroachment can no longer be reversed by returning fire to the system; manual removal is required. Following shrub removal, subsequent burning will deter additional shrub encroachment. Consider retaining randomly-distributed thickets of native shrubs and small trees as habitat structural elements for wildlife (unless you are managing for obligate grassland birds).

Step 4c: Address sedimentation. Sedimentation can be a difficult disturbance to correct, and often all the practitioner can do is prevent further sedimentation from occurring. If sedimentation is related to erosion from surrounding uplands, install silt fences or establish vegetation buffers to capture sediment before it enters the wetland.

Step 5: RCG suppression.

In the systems approach, RCG suppression does not begin until system variables and feedbacks that contribute to invasions have been addressed.

Competition variance: The Achilles' heel of RCG

Competition-invariant species (e.g., garlic mustard and crown vetch) can invade a site regardless of canopy structure and diversity. In contrast, RCG is a competition-variant species that cannot invade a remnant community unless a disturbance removes a portion of the existing canopy (Maurer et al. 2003). It is well-documented in the literature that RCG establishment is low in situations where it has to compete with other species. This means that the presence and abundance of native species will supplement and augment suppression efforts, and gives hope that once an invasion is reversed, a diverse vegetation assemblage that utilizes all available niche space and captures surplus resources will prevent subsequent invasions and our restoration efforts can have cumulative effects across the landscape.

Choice of herbicide

Selective herbicide formulations target narrow groups of related plant species. Non-selective herbicides target a wide range of unrelated species. The most commonly used herbicides for RCG suppression are (in order of popularity) glyphosate, clethodim, imazapyr, fluazifop, and imazapic. Clethodim and fluazifop are grass-selective, the others are broad-spectrum. Glyphosate elicits excellent dieback even at low concentrations, yet its long-term utility is limited because it prevents the ability to reestablish replacement species required to augment treatments. The persistent herbicides imazapic and imazapyr share this problem, but they can sterilize soil for at least two growing seasons, sometimes leading to erosion problems. Of the broad-spectrum herbicides, glyphosate has the most utility for reversal projects, especially during the initial treatment iterations at sites retaining a native propagule bank where RCG dominates standing crop. In mixed stands, grass-selective herbicides are a key element of the systems approach because they foster competition variance and augment the reversal effort by setting up a positive feedback involving native species abundance. A diverse herbaceous canopy of native species shades out RCG during its recovery period following herbicide applications, increasing treatment effectiveness. Grass herbicides can be applied to RCG anytime up to flowering (mid-June in southern Wisconsin); after flowering they are less effective because cool-season grasses exhibit lower growth and productivity. Refer to the label of the product you are using for herbicide application rates.

Proper use of herbicides

Additive systems inexpensively (only 10¢ – 50¢ per mixed gallon) enhance herbicide performance. Additives are required for grass-selective herbicides to work effectively. Graminicides are strictly foliar-absorbed; stem-bundle and wicking methods are ineffective with these herbicides. RCG leaves are covered by a waxy epidermis that must be penetrated before foliar-applied herbicides can enter the plant body and elicit phytotoxic effects. **Nonionic surfactants (NIS)** help spread applied herbicide over the leaf surface. **Methylated seed oils (MSOs)** dissolve the epidermis to promote herbicide penetration. A variety of **MSO-NIS blends** are commercially available, and should be added to tank mixtures at a rate of 1 – 3%. When applying grass herbicides to RCG, adequate coverage is essential; > 90% of leaf surface area should be covered when spot spraying and >70% when boom spraying. Clethodim formulations are sensitive to degradation from UV light (fluazifop is resistant), and another advantage of MSOs is they act as a temporary UV protectant. Higher-quality MSOs (organosilicone-based formulations) also lubricate and extend the functional life of sprayer components, and are more resistant to pump-shear degradation than less-expensive alternatives. When applying grass herbicides near sensitive species, **sticking additives** are very useful because they cause applied herbicide to physically stick to treated surfaces, reducing drift and runoff from leaves (the rate for this purpose is 2 – 4%). When mixing herbicides formulated as IPA salts (glyphosate and imazapyr) you should add a 0.5% of a **water conditioning agent** to the water at because calcium ions in hard water will react with the herbicide and prevent its translocation throughout the plant body. Lastly, you should always **clean and neutralize spray tanks before mixing herbicides!** Most practitioners, even many professional contractors, leave out this important step. Use of ‘dirty’ tanks has led to anecdotal reports erroneously claiming grass-selective herbicides are not selective. The herbicide label will have details on how to neutralize herbicide residues in spray tanks.

<u>Step 6</u>: Actively promote native species recruitment.

Plant sedges and forbs (seeds and/or live plants) to provide competition, even in instances when natural revegetation of relic species is occurring. The Reed Canarygrass Working Group developed detailed recommendations and species lists for revegetation of RCG restoration sites.

Step 7: Repeat steps 3, 5, and 6. Multiple-year suppression efforts are required to reverse a RCG invasion because apical dominance in its rhizomes leads to non-uniform distribution of applied herbicide within the plant body. For details on this mechanism, see Annen (2010). At most sites where the initial condition is characterized by RCG intermixed with native sedges and forbs, expect noticeable improvement after completing two or three cycles of burning and herbicide applications. Complete reversal requires 5 – 7 years of management effort, after which periodic baseline scouting and spot spraying are advisable to wipe out any remaining clones and prevent subsequent invasions.

Step 8: Reestablish the original feedbacks characterizing the remnant condition.

Just as negative feedback cycles in a disturbed condition internally reinforce RCG invasions, positive feedback cycles reinforce the remnant condition. The positive feedback set in motion by combining accessory treatments such as burning and active revegetation with selective RCG suppression involves native species recruitment. Figure 2 illustrates the positive feedbacks that force system on a trajectory of recovery.

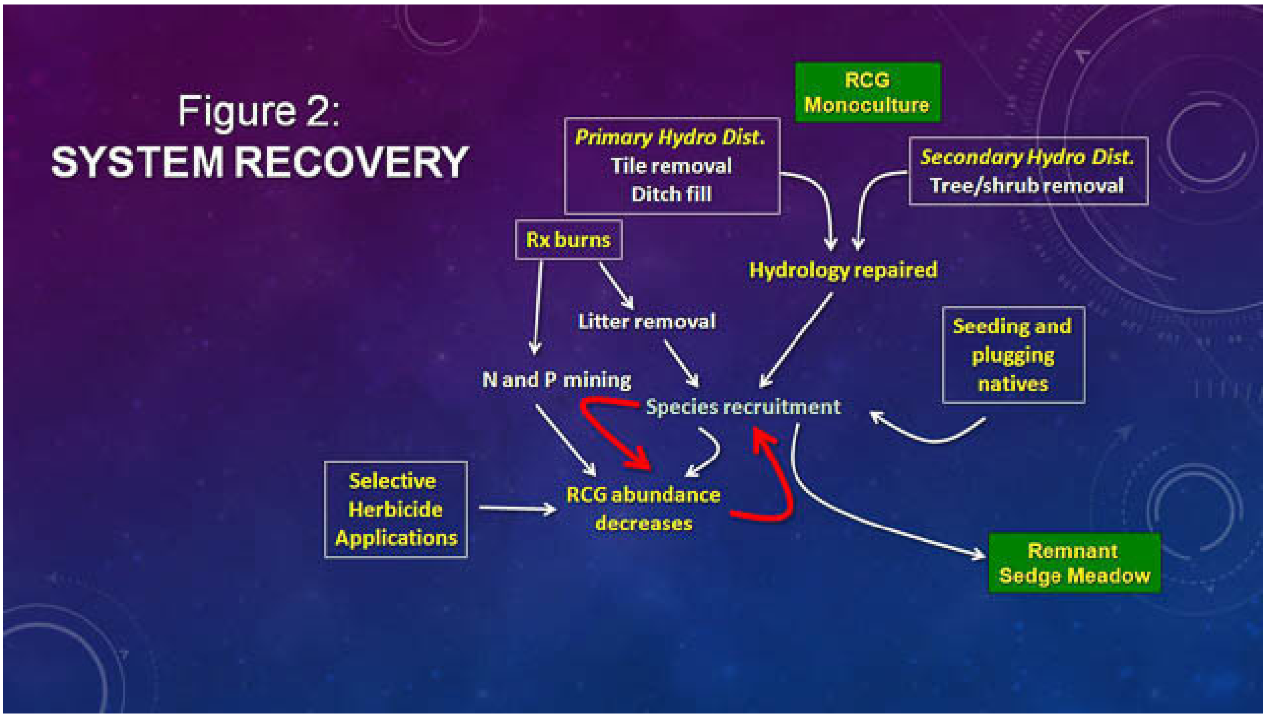


Figure 2:
SYSTEM RECOVERY

RCG Monoculture

Primary Hydro Dist.
Tile removal
Ditch fill

Secondary Hydro Dist.
Tree/shrub removal

Rx burns

Hydrology repaired

Litter removal

Seeding and plugging natives

N and P mining

Species recruitment

Selective Herbicide Applications

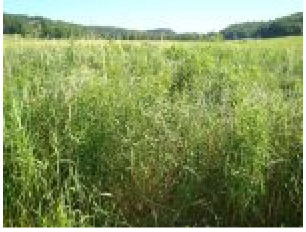
RCG abundance decreases

Remnant Sedge Meadow

Concept maps of system variables and feedback cycles involved in system recovery

Annen (2011) presents a case-study of how this systems-based approach was used to successfully reverse a RCG invasion in a 26-acre sedge meadow remnant in southcentral Wisconsin. Today, this once degraded site is now a high-quality remnant supporting over 200 native species across multiple trophic levels.

The degraded sedge meadow has been returned to remnant condition, dominated by Carex sedges. Note how restoration also changed the physical structure of the vegetation, with implications for wildlife.



Sedge meadow in degraded condition, dominated by RCG and other aggressive species.

Further Reading

Annen, C.A., R.W. Tyser, and E.M. Kirsch. 2008. Reed canarygrass invasions alter succession patterns and may reduce habitat quality in wet meadows. **Ecological Restoration** 26(3):190-193.

Annen, C.A. 2010. Prospects for disrupting rhizome apical dominance prior to chemical treatment of *Phalaris arundinacea*. **Ecological Restoration** 28(3):291-299.

Annen, C.A. 2011. Manipulating internal system feedbacks to accelerate reed canarygrass (*Phalaris arundinacea*) control: From theory to practice. **Ecological Restoration** 29(3):222-224.

Curtis, J.T. 1959. *The Vegetation of Wisconsin*. University of Wisconsin Press, 657 pp.

Evans. M.W. and J.E. Ely. 1941. Growth habits of reed canarygrass. **Journal of the American Society of Agronomy** 33:1017-1027.

Kost, M.A. and D.D. Steven. 2000. Plant community responses to prescribed burning in Wisconsin sedge meadows. **Natural Areas Journal**20(1):36-45.

Maurer, D.A., R. Lindig-Cisneros, K.J. Werner, S. Kercher, R. Miller, and J.B. Zedler. 2003. The replacement of wetland vegetation by reed canarygrass (*Phalaris arundinacea*). **Ecological Restoration** 21(2):116-119.

Schilling, K.E. and J.R. Kiniry. 2007. Estimation of evapotranspiration by reed canarygrass using field observations and model simulations. **Journal of Hydrology** 337:356-363.

Zedler, J.B. 2009. Feedbacks That Might Sustain Natural, Invaded, and Restored States in Herbaceous Wetlands. Chapter 16 in R.J. Hobbs and K.N. Suding, *New Models for Ecosystem*

Dynamics and Restoration. Island Press.

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