Ecologically Based Invasive Plant Management: Step by Step

By Roger L. Sheley and Brenda S. Smith

One of the most challenging problems for land managers is advancing infestations of invasive weeds. Treating weeds is often really only treating a symptom. A fundamental tenet of Ecologically Based Invasive Plant Management (EBIPM) is that managers must treat the underlying ecological cause of invasion to successfully direct vegetation dynamics toward desired species.

Scientists and managers have been working for years to find ways to address the underlying causes of invasions. There is no silver bullet solution, nor is there one right way to solve invasive plant problems, but EBIPM has great promise for assisting managers in making prudent decisions about invasive plants and restoration on range and wild lands. This management framework offers science-based solutions to aid managers in designing treatment combinations that work best for their land.

There are benefits to using EBIPM over other invasive plant management (IPM) methods. Most of all, the likelihood of success is much greater when the underlying cause of invasion is addressed during management. This ensures that the system is best suited to the desired species you want, and weeds are discouraged from reinvading the area for the long term. This article is a general introduction to a stepwise decision-making process and is intended to provide an overview as a starting place to implement this holistic management process.

EBIPM is Uniquely Essential in Solving Vegetation Management Problems

Implementing successful restoration can be demanding when we are trying to predict what changes in vegetation will occur after management. Although it would be wonderful if a "one size fits all" answer was available to solve invasive plant problems, the reality is it takes a manager working with site-specific knowledge to create the best opportunities for establishing desirable plants. The EBIPM model is essentially a thought process incorporating ecology directly into decision making, using a unified framework for structured decisions. By organizing and clarifying ecological information along with the direct knowledge managers have about their landscape to guide decision making, desired vegetation can be restored. Therefore, if managers want to improve their success, they can look beyond treating the weed and determine how to alter the ecological processes that could be directing invasion.

What makes EBIPM unique from other models is that it pulls together ecological theories and principles into a single, unified framework for managers to apply practically. Combined with managers' experience, the model provides a road map they can use to develop effective programs in a way to blend ecology and integrated pest management strategies together to manage invasive species. Even though this model has been developed to help manage invasive species, it is applicable in a wide variety of range and wild land situations.

Ecological Background

The progression of species appearing on the landscape over time is called succession. Retrogression toward nonnative plants that creates monocultures and harms the environment and economy is called invasion. Succession and invasion are linked to many ecological processes that, together, determine the magnitude and direction of vegetation change. An ecosystem with an invasive species infestation can be the result of any or all three causes of succession in disrepair.[1] These three causes are: 1) Site availability. Are there places (niches) for a plant to grow on the site? 2) Species availability. Are there seed sources for desired species or invasive species available to occupy the site if niches are available? and 3) Species performance. Are optimum levels of resources available and herbivory limited to allow the plant to perform (grow and reproduce) to its maximum capabilities?

Managers can manipulate these causes to direct successional changes toward more desirable species in plant communities. There are several processes that direct causes of succession and by managing them in a way to favorably influence the processes, we can improve our success rates. The EBIPM model combines ecological principles with a systems approach to develop invasive plant management plans.

Because management practices are aimed at altering ecological processes to affect succession, understanding the actual cause of invasion becomes more important. But, what exactly are ecological processes? An ecological process can be

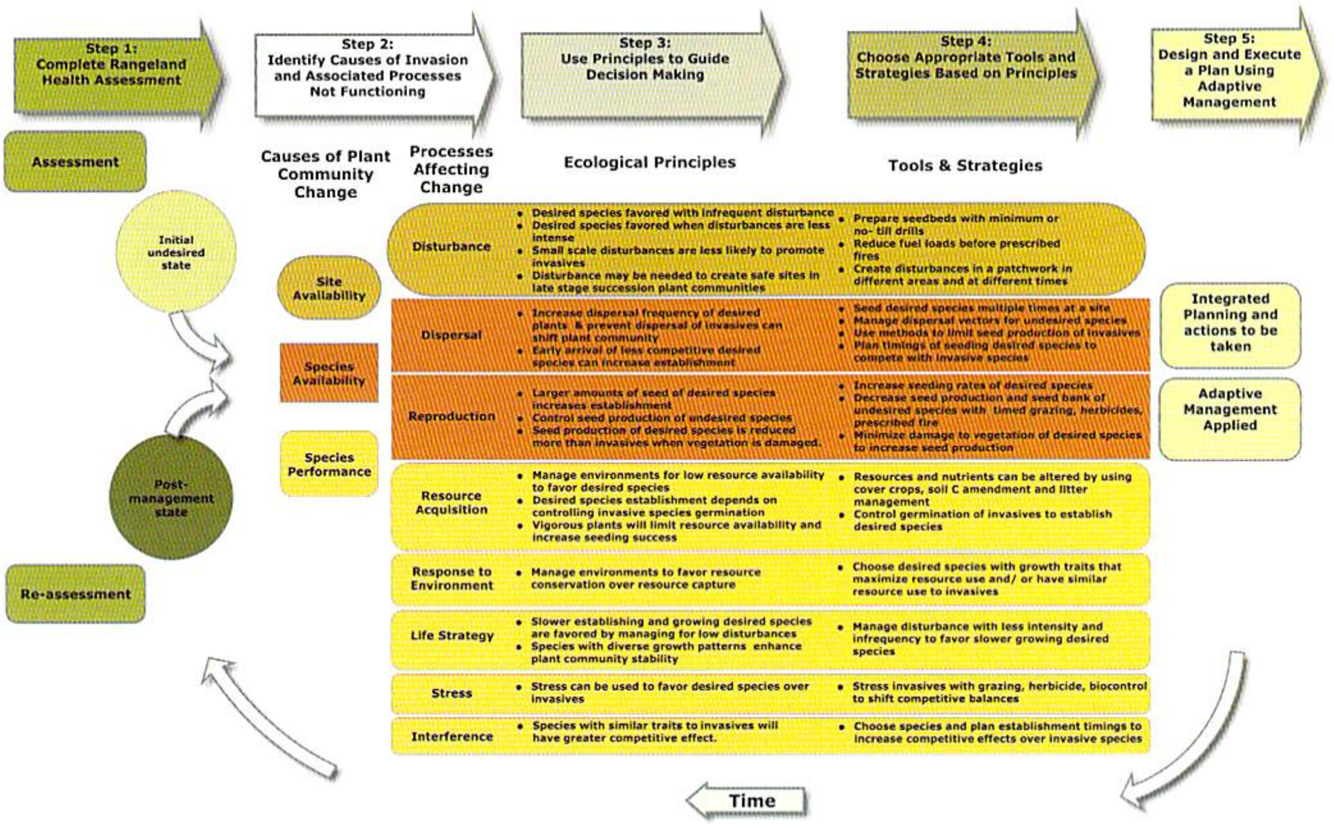

Figure 1. The EBIPM step-by-step decision model.

disturbances (created by any number of activities from fire to grazing), dispersal of seeds or plant parts, herbivory, competition, allelopathy, the availability of resources, and many more. Processes influence one or more of the three causes of succession. EBIPM provides a method for managers to manipulate these processes in a systematic way to create desirable changes in vegetation composition and abundance. Because so many variables can affect ecological processes, it can get complicated. To make it relatively simple and useful, EBIPM provides "ecological principles" that suggest the kind of modification needed to favor desired species or discourage undesirable vegetation. Each principle is based on the associated ecological process and suggests how to alter the process, and thus, succession.

Applying EBIPM: Step by Step

The EBIPM decision model is a comprehensive decision tool that can be broken down in a step-by-step format for anyone wanting to implement effective invasive species management (Fig. 1). In the remainder of this paper, we will examine the steps of this model.

Step 1: Complete Rangeland Health Assessment

A basic component of land management is to assess the current land situation in order to identify ecological processes that are in need of repair. Most government agencies are in the process of implementing "the rangeland health assessment"[i] as protocol. The rangeland health assessment can be enhanced by using this information to determine decisions about repairing or replacing ecological processes during management. The rangeland health assessment uses a series of codes for making determinations of 17 indicators of ecological processes. The range of these codes is based on the deviation of each indicator from the expected conditions of the assessment site. With the EBIPM model we have linked these codes to our ecosystem indicators. The further the code deviates from the expected, the more likely the processes associated with the indicator variable need to be repaired or replaced. We have developed a worksheet to use the information gathered during a rangeland health assessment as the initial step in applying EBIPM (Fig. 2). To begin implementing EBIPM, a user's guide to rangeland assessment has been developed.[ii]

Step 2: Identify Causes of Invasion and Associated Processes Not Functioning

Central to implementing EBIPM is recognizing that the three causes of succession might not be functioning properly. Recognizing these three causes of succession and planning

[i] For more information on rangeland health assessment, see http://usda-ars.nmsu.edu/monit_assess/monitoring.php.

[ii] The Guide to Rangeland Assessment can be accessed through the EBIPM Web site at http://www.ebipm.org/order-our-products.

	Causes of Succession		
Rangeland Health Indicators	**Site Availability**	**Species Availability**	**Species Performance**
Rills, water flow patterns, pedestels, and/or terracettes, gullies, wind scoured, blowout depositions, litter movement	Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight		
Bareground, soil surface loss or degradation, soil surface resistance to erosion	Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight		Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight
Plant Community Composition		Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight	Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight
Compaction Layer	Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight		Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight
Functional/Structural Groups		Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight	
Plant mortality/ decadence	Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight		Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight
Litter Amount			Extreme / Moderate to Extreme / Moderate / Slight to Moderate / None to Slight

Figure 2. EBIPM rangeland health assessment worksheet.

management treatments with the idea that managers need to address the underlying cause of invasion rather than merely cover up the symptoms increases the likelihood of success and sustainability.[2] A comprehensive understanding of each cause of succession provides the knowledge necessary to determine an integrated management plan.

Site Availability. Site availability is most often associated with the process of disturbance. Disturbance is a temporary change in the usual environmental conditions that can cause a pronounced change in an ecosystem. Some examples of natural disturbances include floods, wildfires, windstorms, and insect outbreaks. Human-caused disturbances can occur any time our behavior changes the usual order of nature. When these changes happen, they often open up areas to new or different plants by creating a change in conditions, altering the natural succession of plant communities. Disturbance reduces the intensity of plant competition, changes environmental conditions, and alters the supply rates of resources. One way to direct plant communities toward the desired outcome is to alter these disturbances. Doing this shapes the factors to favor germination, establishment, and growth of the native species over invasive species.

Species Availability. Species availability is a cause of succession directly related to the presence or absence of viable propagules, reproductive or vegetative, brought in by dispersal or present in the soil seedbank. Changes in available seeds can alter plant densities of particular species. When this happens, there is often a shift in the competitive balance of the plant population. In other words, by manipulating species and the quantity of seeds that are available, desired plants are enhanced to shift the competitive balance in their direction.

Species Performance. The third cause of succession is species performance, or how well a species grows and reproduces in different environmental conditions. There are several factors influencing the ability of a species to perform and survive in diverse environmental conditions: 1) resource availability and the ability a species has to capture and use those resources; 2) ecophysiological plant traits, or a plant's ability to adapt to its environment; 3) trade-offs associated with life history strategies; 4) stress and a species' ability to either avoid or tolerate stress; and 5) the way individual plants are influenced by neighbors of different species, often referred to as interference.

If extra resources become available, whether by disturbance or some other means, weeds will typically take advantage of those resources before the native desired species. For example, spotted knapweed (*Centaurea stoebe* L.) is more successful than native species in soils with high soil phosphorous availability. By using this type of information, the factors influencing how species perform can be manipulated. Controlling these factors can be critical in promoting desired species.

Step 3: Use Principles to Guide Decision Making

Ecological principles can be best described as "axioms" that can be followed when land managers are making invasive plant and restoration decisions. Much like engineers who depend on the principles of physics in their work, ecological principles are emerging in the literature and ecologists can begin to bring them into use for restoration work. Principles are derived from scientific literature and they provide an ecological objective based on how an ecological process can be altered to create desired vegetation changes.[3] For example, if we knew we needed to improve site availability for desired species, then the ecological principle here is that *lower disturbance intensity will favor establishment of the desired species.* Based on this principle, choosing tools or strategies that will minimize disturbance will be a key in developing a plan. There might be more than one principle for any given process and there are likely multiple processes to consider for each of the three causes of succession used in this framework. Another benefit of this method is it blends and organizes knowledge into a useful series of principles used to make management decisions.

Step 4: Choose Appropriate Tools and Strategies Based on Principles

Using this step, possible tools and strategies are identified to develop treatments. The ecological principles from the previous step give a manager a better understanding of ecosystem processes and how damaged processes might be responsible for directing successional patterns in a negative direction (presence of invasive species). This creates a stronger basis from which to make informed land management decisions.

In this step, the main work is to determine treatment choices and timing to get the best possible response from the tools and strategies chosen for a specific site. A benefit of linking ecological principles to tools and strategies is that it provides a basis to evaluate and compare various techniques and tools as a plan is developed. The ecological principles are the targets to try to hit as treatments are planned to stimulate favorable vegetation.

Step 5: Design and Execute a Plan Using Adaptive Management

EBIPM provides a method for developing management plans and predicting their outcome. However, because of the number of factors and variables at play, the true effectiveness of imposed management is almost impossible to predict. Adaptive management can empower managers to manage in the face of uncertainty and to learn by doing. The idea of adaptive management has been considered in many ways, but the question is: what exactly is adaptive management? The process of adaptive management involves formulating management questions, choosing management techniques to test these questions, and applying these techniques to the landscape using the basic principles of experimental design.[4] Once treatments are applied to the landscape, data are collected and analyzed. The findings from data collection lead to the next management step. Benefits include a stronger knowledge of the system and greater confidence that the management strategy chosen is the best alternative for the site. Another benefit is a scientifically valid and easy-to-defend management program. In addition, adaptive management promotes the most efficient use of funds. Increased use of adaptive management will also boost the ability to improve decision making over time. A basic position of adaptive management is that treatments should be applied in conjunction with a control area so "cause and effect" can be determined through monitoring and comparing management with a control. Although most land managers know they cannot simply apply treatments and then walk away, monitoring with a control is a key aspect of lasting, effective management.

Applying EBIPM: A Case Study to Guide Restoration

The best way to demonstrate applying EBIPM is to use an example from a case study at three different sites.[5] The overall goal in this example was to restore desired native plant communities to pre-European settlement conditions with the focus on ecosystem organization, structure and function. It was anticipated that once this goal was achieved, the resulting better-functioning system would begin resisting the invasive weeds.

In *Step 1,* three sites were assessed using the rangeland health assessment protocols in a heterogeneous ephemeral wetland (an area with various different species that is wet during some portions of the year and dry during most of the year). The area was dominated by invasive plants, mainly spotted knapweed, sulphur cinquefoil (*Potentilla recta* L.), and cheatgrass (*Bromus tectorum* L.).

Step 2 was to use this assessment information to determine the causes of succession that appeared to be in disrepair.

Step 3 was to link the ecological principles associated with ecological processes that appeared to be in disrepair to identify tools and strategies that could be applied for management.

Step 4 was determining the best treatments to apply.

And finally, *Step 5* was to establish a control and various treatment combinations and then monitor the sites over time to determine if what was being applied was working.

Case Study Site 1

The assessment indicated that site availability was adequate for establishment of desirable species as a result of the disturbance from the rodents. Species availability for desired plants was insufficient due to only a remnant population of native species. Species performance was poor because of the dry soils. The principles that link these processes in need of repair to the most appropriate tools and strategies are:

Site availability. "Desired species will be favored when disturbances are less frequent and intense." Because rodents had created bare ground, adequate safe sites were available so no further management was required to enhance site availability.

Species availability. "Seeding with desired species and limiting dispersal from invasive plants can shift to a more desirable plant community." At this site, the strategy was to increase desired species propagules by seeding.

Species performance. When resources are limited, as in this case with soil moisture, the principle is: "*desired species must first be successfully established to benefit from management of the resources.*" The strategy adopted in this situation in response to understanding the processes in disrepair was to drill desired species seed to create the best possible seed-to-soil contact and provide temporary irrigation to determine if early watering gave desired species the needed requirement for germination.

Case Study Site 2

At site 2 in this case study, the initial assessment found site availability inadequate with few safe sites for establishment of desired species. There was a remnant (20% intact) stand of desired species that likely produced enough seed to reoccupy the site, so species availability was adequate at this site. However, invasive species seed production needed to be limited and the invasive species stressed to give a competitive advantage to the desired species. At least two processes needed to be addressed with regard to species performance. As with site 1, because the soils were xeric at this site, establishment of desirable species needed to be managed successfully. Ecological principles that link the processes in disrepair making the best choices for tools and strategies to manage this site for successful plant establishment are as follows.

Site Availability. "*Desired species will be favored when disturbances are less frequent and less intense.*" A disturbance was needed at this site, but based on this principle, a light disc was chosen to create a low-intensity disturbance for additional safe sites.

Species availability. Because there was an adequate remnant stand of natives and seed production for the desired species was adequate at this site, species availability was not managed.

Species performance. The principle addressing species performance in this case is to "*inhibit the performance of invasive species in low-nutrient environments by stressing the plants.*" For this site, an herbicide was determined to be the best tool to create the needed level of stress on invasive plants. Because the soil type was similar to site 1, the principle *of "desired species must first be successfully established to benefit from management of the resources"* also applied, but in this case a different tool was chosen. After the disking, the soil was lightly imprinted as a way to create safe sites with small hollows that would more effectively collect moisture to enhance germination of the desired seeds.

Case Study Site 3

The third site in this study was located next to a wetland and had higher soil moisture. However, the assessment showed that disturbance was needed to create safe sites. Few native species were remaining, so species availability needed to be increased. The area was heavily infested with invasive species. Soil moisture was not limiting establishment for desired species at this site but the site's heavy infestation of invasive species created interference.

Site availability. The principle to guide the choice of tools for site availability is: "*desired species will be favored when disturbances are less frequent and less intense.*" A disk was selected as the tool to create safe sites. Although disking can create a more intense disturbance than other forms of tillage, it was felt that because the site was already heavily infested and because the soil moisture was not limiting, the desired species would be able to compete if species availability and species performance were addressed.

Species availability. This was addressed with seeding desired species at a higher rate. The principle guiding this decision was: "*Seeding with desired species can shift to a more desirable plant community.*"

Species performance. The principle "*desired species that take up resources similar to invasive species will compete better on a pound-to-pound basis*" links to the strategy to use desired species with traits that can exploit the higher soil moisture. In this case, after disking the area, it was seeded with a diverse group of desired species that could perform well in the higher moisture conditions to effectively interfere with invasive species. In this example, a multiple treatment EBIPM program was designed to repair the various processes and address the cause of successional dynamics as ecological conditions vary across the landscape.

Winning Against Invasive Plants with EBIPM

In our case study, alternative management strategies were tested during management. In our test, EBIPM increased the chance of restoration success by 66% over traditionally applied IWM. Sustainable invasive plant management and ecosystem restoration can only be achieved if the underlying ecological causes of invasion are repaired. Management must favor successional dynamics toward a desired plant community and the ecological function that provides valuable goods and services to society.[6] EBIPM is a stepwise thought process that managers can use to address underlying ecological processes that direct vegetation dynamics to enhance their likelihood of successfully restoring degraded ecosystems.

References

1. Monaco, T. M., and R. L. Sheley [eds.]. 2012. Invasive plant ecology and management: linking processes to practice. Cambridge, MA, USA: CABI. 204 p.
2. Pokorny, M. L., R. S. Sheley, C. A. Zabinski, R. E. Engel, T. J. Svejcar, and J. J. Borkowski. 2005. Plant functional group diversity as a mechanism for invasion resistance. *Restoration Ecology* 13:448–459.
3. James, J. J., B. S. Smith, E. A. Vasquez, and R. L. Sheley. 2010. Principles for ecologically based invasive plant management. *Invasive Plant Science and Management* 3:229–239.
4. Reever-Morghan, K. J., R. L. Sheley, and T. J. Svejcar. 2006. Successful adaptive management—the integration of research and management. *Rangeland Ecology & Management* 59:216–219.
5. Sheley, R. L., J. J. James, and E. C. Bard. 2009. Augmentative restoration: repairing damaged ecological processes during restoration of heterogeneous environments. *Invasive Plant Science and Management* 2:10–21.
6. Sheley, R. L., and J. K. Petroff [eds.]. 1999. Biology and management of noxious rangeland weeds. Corvallis, OR, USA: Oregon State University Press. 438 p.

Authors are Rangeland Ecologist (Sheley), and Research Agronomist, brenda.smith@ars.usda.gov (Smith), USDA-ARS Eastern Oregon Agricultural Research Center, Burns, OR 97720, USA.