Advancing EBIPM Through Education

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Various technologies are available for managing invasive plants and restoring desirable plants on rangelands, but acceptable long-term control and restoration can only be achieved when integrated management approaches focus on the ecological processes driving plant community change and not on particular plant species or manipulation practices.[1] A conceptual framework, such as the one developed for ecologically based invasive plant management (EBIPM), can help managers visualize and understand the linkages among site assessment, ecological processes, vegetation dynamics, and manipulation practices, and make more effective invasive plant management decisions.[2]

The adoption of ecologically based programs like EBIPM on individual ranches or larger landscape scales can be influenced by a variety of factors, including 1) land manager and decision-maker understanding of ecological concepts and manipulation practices; 2) land manager and decision-maker perceptions of program complexity and cost, alternative manipulation practices, and short-term vs. long-term management planning; and 3) linkages between science and management.[3–5] Education and technology transfer, via workshops, demonstrations, field tours, decision-support tools, curricula, and a variety of media, play key roles in addressing managerial, institutional, and social constraints associated with the implementation of invasive plant management programs.[6–8]

Education and technology transfer are central to implementing long-term, self-sustaining EBIPM programs for invasive plants on rangelands. Our focus in this article is on the outreach education efforts associated with the EBIPM program for invasive annual grasses (cheatgrass [*Bromus tectorum*] and medusahead [*Taeniatherum caput-medusae*]) in the Great Basin. We will describe the development and delivery of educational activities and materials for a variety of audiences in the region.

EBIPM: A Synopsis

The EBIPM framework is a step-by-step decision-making process that managers can use to design, implement, and test science-based solutions to invasive plant management problems.[2] The following is a brief description of each step in the decision-making process (for more detailed descriptions of the steps, see other articles in this *Rangelands* special issue).

1. Conduct Rangeland Health Assessment

The 17 indicators used to evaluate current rangeland conditions at the ecological site level in the Rangeland Health Assessment protocol[9] are used to help identify ecological processes currently in disrepair at a site. Changes in these processes are likely responsible for directing successional dynamics in favor of invasive plants.

2. Identify Causes of Invasion

Assessment information from Step 1 is used to identify the primary cause or causes of succession that appear to be favoring invasive plants. Managers can consider specific ecological processes (disturbance, dispersal, resource availability, competition, etc.) and the degree to which these processes may be acting on the causes (site availability, species availability, and species performance). A central aim of EBIPM is to alter the ecological processes influencing the causes of succession and direct vegetation dynamics in a desired direction.

3. Use Principles to Guide Decision-Making

Ecological principles give managers a stronger, science-based foundation from which to make informed management decisions during the planning process. General principles can link management tools to the ecological processes predicted to influence plant community change, and can be applied across a range of management scenarios, allowing managers to transfer knowledge gained from one situation to another.[10]

4. Selection of Tools and Strategies

Using ecological principles to link tools and strategies to ecological processes in Step 3 provides a basis for managers to evaluate and compare various treatment options as a plan is further developed in this step. Managers focus on treatment timing/sequencing to get the best possible response, based on the resources available.

5. Design and Test Program With the Use of Adaptive Management

Adaptive management is an approach that allows managers to operate in the face of uncertainty and learn by doing. Managers formulate management questions, select treatments to test these questions, and apply and monitor the treatments using the basic principles of experimental design. Adaptive

Figure 1. Participants at the 2011 EBIPM field school in Park Valley, Utah, discussing invasive plant management plans they developed as part of a hands-on, field activity.

management provides the feedback mechanism for adjusting management as knowledge is gained.

What makes EBIPM unique compared to other approaches is that it integrates ecological theories and principles into a single unified framework that managers can practically apply. It also facilitates interactions among managers and scientists in the design of sustainable invasive plant management programs. And when presented in an understandable way, the managerial, ecological, and economic aspects of EBIPM can be used to help policy makers to make informed policy and funding decisions, and to create a greater awareness in the general public about the impacts and management of invasive plants on rangelands.

Outreach Events

To gain widespread adoption of the EBIPM framework, a well-developed outreach and education technology transfer program was strategized as part of the Area-Wide Project for EBIPM for Invasive Annual Grasses. A number of educational opportunities were created to appeal primarily to land managers and producers, but also to policy makers and members of the general public. A foundation of the technology transfer program has been our EBIPM field school. This educational event rotates annually within the five-state region of the Great Basin. Typically, the EBIPM field schools are held at EBIPM research and demonstration sites. These sites were set up at the onset of the project on private producers' property or public lands. Research plots (up to 100 × 100 feet in size) and landscape-scale demonstrations (up to 160 acres in size) were implemented to determine how EBIPM strategies (targeted grazing, prescribed fire, herbicides, and seeding, alone and in combination) could be used to most successfully manage annual grass infestations. Intensive research was conducted in small-scale plots to fill knowledge gaps about the effects of manipulation treatments on soil properties and the dispersal, establishment, and performance of native and invasive species. Larger demonstrations allow scientists and managers to compare the practicality of alternative strategies (in a basic experimental design) at an operational scale and find out which one works best in a particular situation.

The field school concept has been to take our core ideas of EBIPM into the field where participants learn by doing. The format of EBIPM field schools offers attendees the opportunity to learn from ecologists, range and weed scientists, plant physiologists, and university professors in settings that take attendees out into the field to apply concepts and topics being discussed. The field schools have been an excellent venue for adult learners to gain EBIPM knowledge from instructors and presenters and then see, reinforce, and experience that knowledge first-hand. More than 235 land and resource managers have attended EBIPM field schools at the Eastern Oregon Agricultural Research Center in Burns, Oregon (2008); at the Circle Bar Ranch in central Oregon (2009); in the foothills of Boise, Idaho (2010); and on the private ranches of Park Valley in northern Utah (2011; Fig. 1). Attendee feedback has been almost entirely positive. However, in response to suggestions and comments, changes and adjustments are made each year to improve the experience. The field school program has been condensed from a 4-day training, and shaped and adapted into a 2-day educational event.

Additional educational opportunities developed include EBIPM workshops and field tours. More than 340 land and resource managers, producers, and others have attended EBIPM workshops in Jordan Valley, Prineville, and Warm Springs, Oregon, and Reno, Nevada since 2008. EBIPM workshops adapt the format of the field school into a 1-day instructional event, presenting EBIPM concepts in a classroom-type setting and focusing the content on specific situations found in the vicinity of the workshop. EBIPM field tours are designed, essentially, as mini field schools. The format generally includes some classroom-style instruction of EBIPM concepts tailored to the needs of the group and the land management challenges they face. The field tours also incorporate the in-the-field element of the field school, taking attendees out to one or more research demonstration sites to see and experience the concepts presented. Field tours offer participants the opportunity to learn the fundamentals of the EBIPM framework, see its usefulness on a landscape-scale demonstration site, and ask questions and engage in discussions with the scientists involved with the program. Almost 400 individuals have participated in EBIPM field tours and field trips.

Technology and the Internet have provided a platform for virtual field tours. Photographs accompanied by descriptive text afford users the chance to read and learn about a field tour and see the sites, research plots, and results. The 2012 Society for Range Management meeting in Spokane, Washington, was the site of the EBIPM symposium, "Sci-

ence You Can Use: Moving Toward Ecologically Based Invasive Plant Management." The symposium was designed to highlight the recent developments and management implications emerging from research and demonstrations conducted as part of the EBIPM program. The symposium explored the critical link between science and on-the-ground management of serious and widespread annual grass species. Those attending the symposium learned how to apply EBIPM and get the decision support information to begin implementing this management framework upon returning home.

Outreach Products

The development of user-support decision tools has been central in the EBIPM technology transfer program. As of 2012, eight EBIPM guidelines have been produced, designed to assist land managers in the process as they begin implementing EBIPM (Fig. 2). Each guideline describes different components of the step-by-step EBIPM process (Table 1). Another product is the *EBIPM Resource Handbook*, which contains of all of the guidelines as well as additional videos and bulletins that have been developed over the life of the program. Education and outreach efforts have also yielded three instructional videos, several fact sheets, and a prevention management tool called the "weed wheel" (Fig. 3). The videos offer a visual illustration of the EBIPM concepts and methods, complimenting the guidelines, for a complete approach to reach land and resource managers at another learning level. These complimentary products facilitate understanding and aid in EBIPM comprehension for managers.

Figure 2. Eight EBIPM manager guidelines that have been developed to date.

Table 1. Subject matter covered in the eight EBIPM manager guidelines

EBIPM user guidelines	
Applying EBIPM	• Introduction to the EBIPM decision-making process • Overview of the five steps in the EBIPM model • Application of the step-by-step process in case studies
EBIPM assessment guidelines	• Describes how to integrate rangeland health assessment with successional management to identify ecological processes in need of repair for successful restoration
Researching cultivation history	• Explains how to obtain records of cultivation history, which can have long-lasting impacts on site conditions
Ecological principles for invasive plant management	• Illustrates how ecological principles link ecological processes in disrepair to the tools and strategies that can best repair invaded communities
Establishing a weed prevention area	• Provides interested groups with the steps and resources to initiate and develop a weed prevention area
Grazing invasive annual grasses: the green and brown guide	• Describes how to use time-controlled, high-intensity grazing when invasive annual grasses are most palatable (green) and desired species are less palatable/dormant (brown)
Revegetation guidelines for the Great Basin: considering invasive weeds	• Provides a step-by-step guide to the processes and procedures of establishing desired plant species
Adaptive management for invasive annual grasses	• Explains how to use an eight-step process to test alternative management practices and determine which ones work best–"learning by doing"

Figure 3. EBIPM videos (DVDs), bulletins, weed wheel, and screen shot of Web site (www.ebipm.org) that have been developed to date.

Curricula

High School Curriculum

High school students are a particularly appropriate age group for learning about invasive plant ecology and management because they are developing the capability to comprehend complex environmental issues.[11] By gaining knowledge about invasive weeds and a sense of appreciation toward the environment, these students will more likely become involved in future invasive weed management issues. To promote student learning and involvement, a rangeland invasive weed education program should have the following key elements: 1) interested, knowledgeable, and skilled teachers; 2) student-centered, inquiry-based learning; 3) integration and transfer of skills; and 4) a sense of place or connection to the local environment.[12] An effective program also needs to be easy for teachers to use and understand, and meet curriculum content requirements.

The EBIPM high school curriculum (Fig. 4) was designed in a modular format with these instructional elements in mind, and can be used in environmental science, biology, natural resource, and agriculture courses in its entirety throughout a term, as a supplement to a specific class topic, or as a preparation for a field trip. Each module (Table 2) contains background and additional information to assure that teachers, even those with minimal knowledge of invasive weeds, will have the resources needed to effectively teach the curriculum. Inquiry-based learning activities in modules include case studies, plant identification and classification, vegetation sampling and mapping, video/article review and discussion, plant growth experiments, and creation of an adaptive management plan. Many of these activities allow students to conduct their own research, collect and analyze data, address real-world issues, and do projects within their own local areas. Students also will apply and integrate many underlying concepts of science, math, geography, and social studies. Each module has a pre- and posttest to assess student learning, and a listing of the national science education content standards that are addressed.[13] Modules 1–3 introduce students to rangeland ecosystems, plant identification and systematics, and scientific research to prepare them for the five steps in the EBIPM decision-making framework, which are presented in Modules 4 and 5.

University Curriculum

Future natural resource managers and decision-makers attending colleges and universities will undoubtedly encounter

Table 2. Subject matter covered in the five modules comprising the EBIPM high school curriculum

High school curriculum modules	
Module 1: rangeland ecosystems	• Importance of rangelands • Basic ecological concepts • Soil/weather effects on plant communities • Features of healthy and degraded rangelands • Differences between native and invasive plant species
Module 2: plant ID and systematics	• Plant classification concepts • Morphological characteristics and plant identification • Life strategies of native and invasive plant species
Module 3: scientific research	• Scientific method and invasive species management • Vegetation sampling methods and data analysis
Module 4: EBIPM steps 1, 2, and 3	• Step 1: rangeland health assessment • Step 2: causes of succession/processes in need of repair • Step 3: use principles to guide decision-making
Module 5: EBIPM steps 4 and 5	• Step 4: tools/strategies for weed control and restoration • Step 5: design/implement plan using adaptive management

invasive plant management issues in their careers. To fully understand these complex issues and take appropriate actions, students should be exposed to a framework like EBIPM, in which management decisions are based on ecological theory. Individuals who are familiar with the principles that link ecological processes to the relative abundance of desired and undesired species will have a stronger, science-based foundation for evaluating the usefulness of tools and strategies during the planning process.[2] Exposure to EBIPM will also help students recognize the importance of treating the causes of invasion (ecological processes in disrepair) rather than the symptoms (weeds) and use a decision-making framework that can be applied at different scales across heterogeneous environments, allowing the transfer of knowledge from one situation to another.

The university curriculum (Fig. 4) was designed in a modular format so instructors could integrate all or portions of the EBIPM framework into their weed science, invasion ecology, restoration ecology, range management, and rangeland planning courses. Several course design elements were considered during initial curriculum development, including prerequisite knowledge of students (i.e., biology, ecology, and soils back-

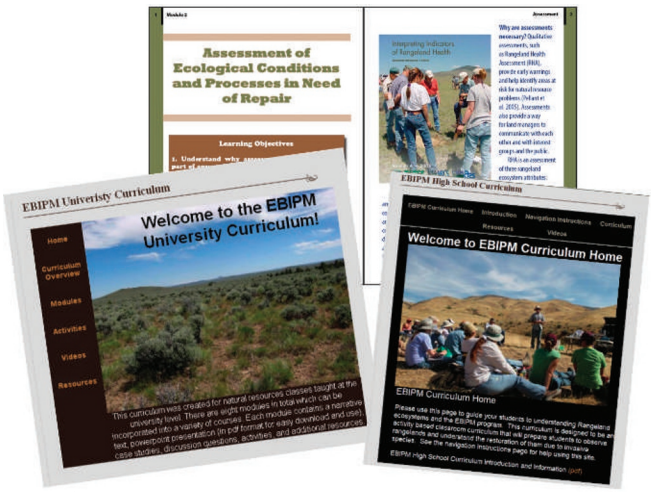

Figure 4. Introductory pages to EBIPM high school and university curricula, and first pages of Module 2 from the university curriculum.

Table 3. Subject matter covered in the eight modules comprising the EBIPM university curriculum

University curriculum modules	
Module 1: introduction to EBIPM	• Traditional vs. ecologically based weed management • Overview of EBIPM approach and framework
Module 2: rangeland health assessment (RHA)	• Importance of assessment in the planning process • RHA protocol and underlying ecological concepts • Integration of RHA and successional weed management
Module 3: causes of succession	• Overview of causes of succession/ecological processes • How causes/processes influence invasion/restoration
Module 4: principles and decision making	• Principles provide a bridge between theory and practice • Principles guide selection of tools and strategies
Module 5: tools and strategies	• Prevention, control, and restoration strategies • Biological, chemical, mechanical and cultural tools • Integration of tools and strategies
Module 6: adaptive management	• Managing complex problems in the face of uncertainty • Management as an experiment: an eight-step process
Module 7: weather variability, seedbed microenvironment, and establishment	• Weather/microenvironment and successional processes • Weather/microenvironment and seedling recruitment • Weather, assessment, and adaptive management
Module 8: human dimensions of invasive plant management	• Federal/state/local policies affecting weed management • Analysis of goods/services and benefits/costs • Stakeholder involvement: conflicts and collaboration

Table 4. Outreach impacts for EBIPM products, activities, and Web site to date

EBIPM outreach impacts	
Products (guidelines, DVDs, bulletins, etc.)	
• E-mail requests	650+
• Delivered	7,000+
Participants/Attendees	
• Field schools	235
• Workshops	340
• Field tours and field trips	360
• EBIPM symposium at 2012 SRM Annual Meeting	65
Total	1,000+
Web site, http://www.ebipm.org (May 2011–May 2012)	
• Visits	6,330
• Page views	16,235
• Contacts	196

ground), learning outcomes, sequencing and integration of content, materials and activities to promote student engagement, and an evaluation component.[14] The individual modules (Table 3) were developed in collaboration with scientists who have presented these topics at EBIPM field schools and workshops, and with other scientists and managers involved in the EBIPM program. Each module contains a PowerPoint presentation, a narrative document (similar in layout to an EBIPM guideline), and a set of activities. Narrative components include learning objectives, content presented as concise text with supporting graphics and examples, case studies that integrate and synthesize content, discussion questions, additional resources, and relevant literature. Associated classroom, field, and laboratory activities foster experiential learning and retention of content. Module 1 provides an introduction to EBIPM, and Modules 2–6 align with the five steps in the EBIPM decision-making framework. Module 7 describes how weather and climate information can be incorporated with seedbed microclimate modeling of plant establishment to determine the success of restoration strategies on annual-grass–infested rangelands. And, Module 8 examines the roles of policy, economics, and stakeholder involvement in invasive plant management.

Online Presence

The EBIPM Web site[i] provides a clearinghouse for the information described above. Users have the option of visiting the Web site at any time to view EBIPM videos (those mentioned as well as videos from EBIPM workshops and the EBIPM symposium at the 2012 SRM meetings); download EBIPM guidelines, bulletins, and other products; see updates on the EBIPM demonstration areas; download and read scientific publications associated with EBIPM; get information about upcoming and past field schools and tours, workshops, and other events; and much more (Fig. 3). Additionally, university and high school curricula are available through the EBIPM Web site. EBIPM.org averages 20–25 visitors on any given weekday and 10–12 per day on weekends. The EBIPM Web site has generated more than 350 requests for products and materials, which have been sent all across the United States and around the world to individuals in Brazil, France, Canada, Argentina, Turkey, Rwanda, Australia, and India.

Impacts of EBIPM Technology Transfer

The combined education and technology transfer products developed to increase widespread adoption of EBIPM have reached broad audiences (public and private land managers, scientists, decision-makers, students, teachers, and other members of the general public), with more than 7,000 guidelines, DVDs, and bulletins delivered; more than 1,000 individuals attending a field school, workshop, field tour and/or symposium; and more than 6,000 Web site visits during a recent 1-year period (May 2011–May 2012) (Table 4). We have direct knowledge that EBIPM is influencing at least 4 million publically managed acres, as land managers with the Bureau of Land Management, US Forest Service, and National Park Service are all working to develop EBIPM management plans for invasive plants on their management areas.

Within the EBIPM research demonstration areas, we estimate that at least 500,000 acres of land have been directly impacted with EBIPM practices, and additionally 2.5 million acres have in some way been indirectly impacted by more successful management of annual grasses by incorporating EBIPM concepts. Work in Idaho at the Snake River Birds of Prey National Conservation Area is ongoing, with the goal to use the EBIPM approach in the development of environmental assessments on federal lands. It has been difficult to determine the exact number of universities and high schools adopting EBIPM curriculum modules, since they are available online. However, in direct feedback from instructors we know of at least six universities and three high schools using either all or parts of the developed modules.

[i] www.ebipm.org

The results of this multiagency collaborative effort have clearly shown the value of a comprehensive technology transfer program. With the products developed, and the creative outreach conducted, EBIPM concepts are being implemented on a large scale throughout our Western rangelands and are improving invasive annual grass management. The continued availability of research and demonstration findings, outreach products, and high school and college curricula on the EBIPM Web site after the field portion of the project has been completed in 2012 ensures that the EBIPM approach will continue to reach a variety of audiences in the years to come.

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