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# Management of Plant Invasions: The Conflict of Perspective[1]

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**Abstract:** During the past decade, as the issue of plant invasion gained recognition in the public domain, both ecologists and weed scientists voluntarily or by mandate moved to provide their ex-
?1 pertise to the management of invasive plants on public lands. Diverse views of nature carried to the table by ecologists and weed scientists have resulted in different priorities and opinions on management strategies. However, both groups share the goal of protecting natural resources for the public good. Efforts to achieve consensus among ecologists and weed scientists should acknowledge and resolve how and why the two groups come to different views of nature. Then, areas of mutual strength need to be identified so that improved management or restoration plans can be developed.
**Additional index words:** Ecosystem management, restoration.

## INTRODUCTION

Plant invasion of public lands has emerged as a cross-disciplinary issue regularly involving ecology and weed science (Luken 1997). Historically, few resource management issues simultaneously invoked these two disciplines because ecologists focused their attention on systems managed for biodiversity (e.g., nature preserves, national forests, national parks), whereas weed scientists focused their attention on systems managed for commodities (e.g., turf, agricultural fields, tree plantations). During the past decade, as the issue of plant invasion gained recognition in the public domain, both ecologists and weed scientists voluntarily or by mandate moved to provide their expertise. The diverse views of nature carried to the table by ecologists and weed scientists often lead to different priorities and opinions on management strategies. However, both groups share the goal of protecting natural resources for the public good. Successful management of plant invasions in the future will likely require multidisciplinary approaches where weed scientists and ecologists work side by side. The purpose of this article is to demonstrate that both weed scientists and ecologists can provide valuable expertise within the context of ecosystem restoration.

**The Lasting Influence of Training.** Concepts of nature and the perceived role of humans in shaping nature are likely forged during undergraduate and graduate training. A quick survey of undergraduate and graduate programs in ecology and weed science suggests that artificial academic boundaries delineating colleges and departments may be high and thick, although both disciplines are characterized by moves toward greater levels of interdisciplinary research. Academic programs in ecology are heavy in theory but require almost no coursework in economics or management of commodity production systems. Academic programs in weed science are heavy in management but require almost no coursework in plant or theoretical ecology. Conservation biology is rarely required in either discipline. There is, however, some evidence that both groups have borrowed and modified ideas and concepts from one another. For example, almost all weed science programs require a course in weed ecology where students learn about weed interactions with crops as well as spatial variation of weed populations in fields. Ecologists, on the other hand, have borrowed the weed concept to make the case that plant invasions are indeed a critical problem on public lands and thus are deserving of more ecological research or management efforts.

Ecologists appreciate long-term system trends as modified by natural rather than human disturbances and their management goals often focus on structure, function, and biodiversity of ecosystems. Weed scientists appreciate short-term population trends as modified by human disturbances and their management goals focus on tangible production. A similar dichotomy in goals was noted by McNaughton (1993) when he assessed the interaction between ecologists studying natural grazing systems and range scientists studying agricultural grazing systems.

In the arena of plant invasion, there is indeed opportunity for both groups to make valuable contributions to

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management plans. However, each group will need to modify somewhat their learned paradigm because of the fact that most public lands now experiencing plant invasions support multiple-use ecological systems (Kessler et al. 1992). These systems have long histories of human modification; human modification will continue in the future. These systems do not fit the ecologist's version of unbridled nature; neither do these systems fit the weed scientist's version of bridled nature. For example, ecologists would do well to recognize that many public lands are mandated to function as commodity production systems. Although the commodities may be difficult to value (e.g., recreation, aesthetics), management for these commodities may not contribute to biodiversity goals and may also create disturbances that contribute to invasions (Mack et al. 2000). Weed scientists, on the other hand, would do well to recognize that any management of natural vegetation (e.g., successional communities with relatively high richness) is likely to change the long-term trend of the system (Walters and Holling 1990). Short-term successes in management may not emerge as long-term successes. In summary, ecologists could better appreciate the influence of economics on natural systems, weed scientists could better appreciate the unpredictability of system trends over the long term. The following case study suggests that management of plant invasions on public lands is indeed a complex social activity and that ecologists and weed scientists are still far from achieving synergy.

**Management of Diffuse Knapweed Along the Colorado Front Range.** Local governments are responsible for managing over 50,000 ha of public lands in and around the Boulder area of the Colorado Front Range. These lands provide open space and are used for various combinations of passive recreation, biological conservation, and agriculture. Some of these lands are now managed for the control of invasive plants, including species with large regional distributions such as diffuse knapweed (*Centaurea diffusa* Lam. #[3] CENDI). Woodall et al. (2000) documented the social dilemmas faced when conducting relatively controversial management activities such as large-scale herbicide treatment of public lands. As mentioned in the report of Woodall et al. (2000), aerial spraying for diffuse knapweed was initiated by public land managers in Boulder County, CO, in 1996. A lawsuit, eventually dismissed, by citizens opposed to aerial spraying was brought against the County. Aerial application of herbicides was again proposed in 1997, without providing an analysis of 1996 results or without providing nontarget effects on plant species in the Boulder area. Local ecologists expressed concern about the absence of monitoring of nontarget effects, an essential activity when one needs to know how the system is responding to management activity (Christensen et al. 1996; Noss 1999). Although the literature indicated that herbicide treatment would provide reductions in the densities of the target species, the widespread presence of the plant and its ability to recolonize herbicide-treated areas from either tumbleweed or seed bank sources suggested that herbicides as a one-time activity was not going to achieve control (Beck 1995; B. F. Roche and C. T. Roche 1999).

By the end of 1998, limited monitoring of diffuse knapweed indicated that the plant was not a short-term threat to native biodiversity. It was argued that research on system trends and alternative control methods should be conducted before once again spending large sums on broadcast spraying of established knapweed populations. However, this argument was challenged by weed scientists: herbicides killed plants and therefore herbicides represented proven technologies. Ecologists argued that temporary reduction of plant densities was not a long-term solution.

At the request of County Commissioners, after a hearing in April 1997, an ecosystem management approach to examine control of diffuse knapweed populations using both bottom-up (plant competition and resource manipulations) and top-down (classical biological control) approaches was initiated. The testing of biocontrol insects in particular had not been performed in the Colorado Front Range. Previous research on biocontrol of diffuse knapweed in other areas gave negligible effects (Carpenter and Murray 1999; Smith 2004); however, such studies did not include the suite of biocontrols approved for use on diffuse knapweed because of limited availability of the insects. Biocontrol insects were released although ecologists are, in general, concerned about nontarget effects of nonindigenous insect species (Louda et al. 2003; Simberloff and Stiling 1996) and although weed scientists do not generally appreciate these insects because of their apparent lack of damage to target species (DeLoach 1997). Unique chemistry of *Centaurea* species provided the expectation of few or no nontarget effects (i.e., the insects were specialists), and a few hundred each of several species of biocontrol insects were released at the study site in 1997. Somewhat surprisingly, by 2001, insects had reduced densities of

[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

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knapweed below those suggested as acceptable target levels. This research program eventually led to the publication of a management approach that at least equaled the efficacy of herbicide treatment, that had zero cost to the County, and had no known nontarget effects (Seastedt et al. 2003; Suding et al. 2005). In summer 2001, site tours were given to land managers, and the local papers carried these findings. The reduction of knapweed increased at the demonstration site in 2002 and 2003, and continued presentations and reports to managers were made. In early 2004, broadcast spraying in Boulder and in Colorado remained the standard and accepted management approach for diffuse knapweed. Yet, pastures treated with herbicides in 1996 and 1997 had returned to their pretreatment densities of knapweed by 2001.

**The Case Study in Retrospect.** This case study dealing with diffuse knapweed reflects many of the complex issues associated with managing public lands for sustainable use (Ludwig et al. 1993). On the surface it appears as a relatively simple problem: weeds are present, eliminate the weeds. However, in reality, the situation developed into a battle of opinion over the most appropriate management approach. Notice that the weed scientists were managing, that is what they are trained to do. Notice that the ecologists were studying long-term system trends, that is what they are trained to do. On the one hand, ecologists viewed herbicide spraying as a short-term fix with many potential nontarget effects and no proven long-term benefits. On the other hand, weed scientists viewed monitoring, the biocontrol release, and soil and plant competition manipulations of ecologists as having little immediate or widespread effect on the problem at hand.

Elements of the knapweed case study are not unique. Indeed, most prominent plant invaders of public lands are subject to a variety of control methods, and there is a growing volume of published literature documenting success or lack of success (Anderson et al. 1996; Luken 1997; Mack et al. 2000). However, when these control methods are moved to the operational phase, it quickly becomes clear that the success or failure of a management method to control plants represents one small part of protecting natural resources for the public good (Wagner 1996). Indeed, many questions should be raised and answered before any management is undertaken on public lands. In this study, we present a list of those questions, but such lists have been iterated a number of times in the past decade (Byers et al. 2002; Christensen et al. 1996; Ludwig et al. 1993; Noss 1999; Wilson and Lantz 2000).

Initial general questions about the invaded system are as follows: (1) Who are the stakeholders associated with the public lands? (2) What are the critical natural resources that need to be protected? (3) Where are the critical resources? (4) What are the relative threats to the critical resources? (5) Considering the stakeholders, what are the resource-use goals for the vegetation? (6) What are the long-term trends in the system?

Initial specific questions about invasion ecology are as follows: (1) What are the major disturbances in the system? (2) What are the historical trends for species loss (extirpation) and addition (introduction)? (3) What system characteristics are modified by human activities? (4) How are invasive species working against management goals? (5) How are invasive species contributing to management goals? (6) What are the true invaders and where are they located?

Initial specific questions about managing invasions are as follows: (1) What are the management options? (2) How will management affect long-term trends in the system? (3) Will management contribute to restoration of the system? (4) Will management have nontarget or offsite effects? (5) Has the public been adequately informed about planned management? (6) Are management resources being allocated based on prioritized threats?

The sheer number of questions, usually unanswered, associated with managing invasions of public lands is typically sufficient to discourage many ecologists and weed scientists from participating in the process of protecting public resources (Walters and Holling 1990). Those that become involved in the process quickly gain an appreciation for how difficult it is to answer these questions especially when monetary resources are limited. It should not then be surprising to find that many resource managers, regardless of educational background, make assumptions and then act based on what can be easily done and based on what has been done in the past with observable results. In the case of invasive plants, the assumption is commonly that the plants should be killed or removed. Furthermore, spraying of herbicide to kill plants is encouraged by a large array of relatively cheap products, product support, application technology, and readily observable results. This approach is personally and professionally satisfying because the results of herbicide application are usually apparent even to the general public.

**Reconciliation Through Restoration.** There are now numerous examples suggesting that direct management

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of invasive plants does not contribute to spontaneous emergence of the preinvasion system (Anderson et al. 1996; Luken 1997; Suding et al. 2004). Often, costly restoration activities are required and in some instances because of system characteristics that facilitate new invasions, the management goal may not be possible (Luken 1997; Solecki 1997). Although this may be discouraging to those people who are directly engaged in the battle against invasive plants, the situation has a bright spot. Restoration ecology has emerged as a workable blend of ecological theory and judicious management (Palmer et al. 1997; Wilson and Lantz 2000). If all invasive plant problems on public lands are recast as restoration problems, then the gap between ecologists and weed scientists becomes less daunting because each group is forced to venture into new and uncharted territory. With restoration problems, ecologists can provide their expertise on factors contributing to biodiversity and system trends, and weed scientists can provide their expertise on management approaches. In addition to providing a new philosophical basis for managing plant invasions, restoration ecology has a long history of direct public involvement (Jordan et al. 1987). Such involvement during the process of developing management plans for public resources is required for many public lands (Kessler et al. 1992). Public involvement in the actual management of plant invasions provides cheap labor and an excellent educational opportunity.

Assuming that the plant invasion issue can be recast as a restoration issue, the future holds more interesting and perhaps more challenging questions. Most important is the crafting of long-term goals for ecological systems that can indeed be met considering human impacts, political influence, and economic limitations (Wagner 1996). Fortunately, there is some evidence to suggest that management of a few key human disturbances will greatly diminish the effect of some invasive plants (Luken and Spaeth 2002). Real progress, however, will come when the efforts to reestablish extirpated species equal or exceed the efforts to eliminate invasive species.

## LITERATURE CITED

Anderson, R. C., S. S. Khillion, and T. M. Kelley. 1996. Aspects of the ecology of an invasive plant, garlic mustard (*Alliaria petiolata*), in central Illinois. Restor. Ecol. 4:181–191.

Beck, K. G. 1995. Diffuse and Spotted Knapweed. Colorado State University Cooperative Extension Fact Sheet 3.110: Web page: http://www.ext.colostate.edu/pubs/natres/03110.htm. Accessed: December 3, 2003.

Byers, J. E., S. Reichard, C. S. Smith, et al. 2002. A call for research needed to reduce the impacts of nonindigenous invasive species. Conserv. Biol. 16:630–640.

Carpenter, A. T. and T. A. Murray. 1999. Element Stewardship Abstract for *Centaurea diffusa* Lamark, Diffuse Knapweed, TNC Wildland Invasive Species Team: Web page: http://tncweeds.ucdavis.edu/esadocs/documents/centdif.html. Accessed: December 31, 2003.

Christensen, N. L., A. M. Bartuska, J. H. Brown, et al. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecol. Appl. 6:665–691.

DeLoach, C. J. 1997. Biological control of weeds in the United States and Canada. *In* J. O. Luken and J. W. Thieret, eds. Assessment and Management of Plant Invasions. New York: Springer-Verlag. Pp. 172–194.

Jordan, W. R., M. E. Gilpin, and J. D. Aber. 1987. Restoration ecology: ecological restoration as a technique for basic research. *In* W. R. Jordan, M. E. Gilpin, and J. D. Aber, eds. Restoration Ecology: A Synthetic Approach to Ecological Research. Cambridge: Cambridge University Press. Pp. 3–22. ?6

Kessler, W. B., H. Salwasser, C. W. Cartwright, and J. A. Caplan. 1992. New perspectives for sustainable natural resources management. Ecol. Appl. 2:221–225.

Louda, S. M., A. E. Arnett, T. A. Rand, and F. L. Russell. 2003. Invasiveness of some biological control insects and adequacy of their ecological risk assessment and regulation. Conserv. Biol. 17:73–82.

Ludwig, D., R. Hilborn, and C. Walters. 1993. Uncertainty, resource exploitation, and conservation: lessons from history. Science 260:17,–36. ?7

Luken, J. O. 1997. Management of plant invasions: implicating ecological succession. *In* J. O. Luken and J. W. Thieret, eds. Assessment and Management of Plant Invasions. New York: Springer-Verlag. Pp. 133–144.

Luken, J. O. and J. Spaeth. 2002. Comparison of riparian forests within and beyond the boundaries of land between the Lakes National Recreation Area, Kentucky, USA. Nat. Areas J. 22:283–289.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences and control. Ecol. Appl. 10:689–710.

McNaughton, S. J. 1993. Grasses and grazers, science and management. Ecol. Appl. 3:17–20.

Noss, R. F. 1999. A Citizen's Guide to Ecosystem Management. Boulder, CO: Biodiversity Legal Foundation. Pp. 20–21.

Palmer, M. A., R. F. Ambrose, and N. L. Poff. 1997. Ecological theory and community restoration ecology. Restor. Ecol. 5:291–300.

Roche, B. F., Jr. and C. T. Roche. 1999. Diffuse knapweed. *In* R. L. Sheley and J. K. Petroff, eds. Biology and Management of Noxious Rangeland Weeds. Corvallis, OR: Oregon State University Press. Pp. 217–230.

Seastedt, T. R., N. Gregory, and D. Buckner. 2003. Reduction of diffuse knapweed by biocontrol insects in a Colorado grassland. Weed Sci. 51:237–245.

Simberloff, D. and P. Stiling. 1996. How risky is biological control? Ecology 77:1965–1974.

Smith, L. 2004. Impact of biological control agents on *Centaurea diffusa* (diffuse knapweed) in central Montana. *In* J. M. Cullen, D. T. Briese, D. J. Kriticos, W. M. Lonsdale, W. M. Morin, and J. K. Scott, eds. Proceedings of the XI International Symposium on Biological Control of Weeds. Canberra, Australia: CSIRO. Pp. 589–593.

Solecki, M. K. 1997. Controlling invasive plants. *In* S. Packard and C. F. Mutel, eds. The Tallgrass Restoration Handbook. Washington, DC: Island Press. Pp. 251–278.

Suding, K. N., K. L. Gross, and G. R. Houseman. 2004. Alternative states and positive feedbacks in restoration ecology. Trends Ecol. Evol. 19:46–53.

Suding, K. N., K. D. LeJeune, and T. R. Seastedt. 2005. The competitive impacts and responses of an invasive weed: dependencies on nitrogen and phosphorus availability. Oecologia In press. ?8

Wagner, F. H. 1996. Principles for conservation of living resources: another perspective. Ecol. Appl. 6:365–367.

Walters, C. J. and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71:2060–2068.

Wilson, M. V. and L. E. Lantz. 2000. Issues and framework for building successful science-management teams for natural areas management. Nat. Areas J. 20:381–385.

Woodall, C., A. Hanler, and L. Broberg. 2000. Social dilemmas in grassland ecosystem restoration. Ecol. Restor. 18:39–44.