PRACTICE AND PERSPECTIVE

Keeping Invasive Plants out of Restorations

by Catherine C. Reed

Developing and implementing a strategic plan for controlling invasive plants will help insure that your restoration site or natural area will be as invasive-proof as possible.

Non-native plants invade about 1.7 million acres (700,000 ha) of wildlife habitat every year in the United States (Pimental and others 2000). There is no doubt that weedy plants (those that persist only in disturbed areas) and invasive plants (those that persist in disturbed areas and in previously undisturbed plant communities) are a serious concern for restorationists. Because they are so aggressive and detrimental to our restoration goals, we must decide whether to manage these species and, if so, when and where to start our management efforts. This paper presents simple procedures for assessing non-native plants in prairie and woodland restorations and provides guidelines for making decisions about how best to manage them.

Restoration Goals and Invasive Species

The first step in any restoration is to set the project goals and objectives. I suggest that during the goal-setting stage consideration should be given to the ways in which invasive species relate to the restoration process.

The ultimate goal of all restoration efforts is to produce a healthy, self-sustaining ecosystem or community (SER 2002). If an additional goal is to protect certain species or to restore certain ecosystem or community functions, non-native species may be acceptable and even valuable, provided they are not invasive (Williams 1997, D'Antonio and Meyerson 2002). If a goal is to re-create presettlement plant and animal communities on the site and/or to return the community to a known predisturbance state, both species and function will have to be restored, and non-native species populations must be reduced as much as possible.

Specific and measurable objectives are the easiest to evaluate. For example, an objective might be to establish populations of 75 percent of the native plant species found at a reference site on the restored area within five years. Approximate target dates for meeting objectives may be set with the time required to reach them estimated according to the life spans of the species being restored (Cairns 1993). Monitoring methods and dates should also be established at the time goals and objectives are set.

Information about the site and species is the bridge between goals and methods. For example, if knowledge of native and non-native plant populations is inadequate, additional goals might include learning as much as is needed about invasive plants on the site. This can involve cataloging and mapping their populations, completing a literature search about a particular species' physiology and ways other people have managed the species, and conducting some small-scale experiments to study different control methods.

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Evaluating the Restoration Site

Once the goals and objectives of the project have been identified, the next step is to map and describe the restoration and its surroundings, identifying both physical and biological features, including the presence and reproduction of native and non-native plant species. The map (like that shown in Figure 1) will be essential in future years for monitoring the success of restoration efforts. In making this map, it is important to describe 1) the patches that make up the managed area, 2) the surrounding landscape, and 3) the edges and corridors that connect the two.

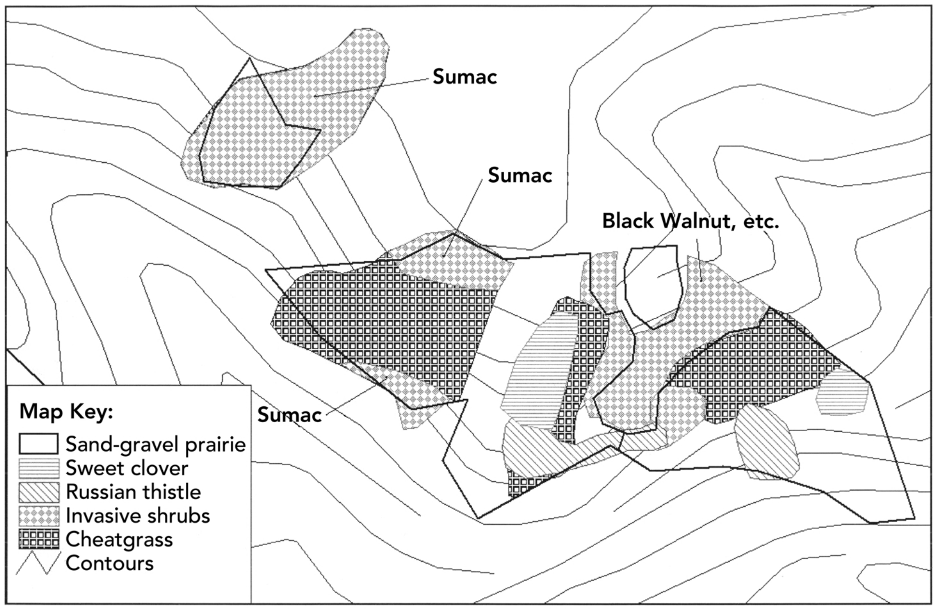

Figure 1. Mapping areas where invasive species are present is key when developing restoration and management strategies and for monitoring once those strategies have been put into place. *Courtesy and with permission of Great River Greening.*

Patches

Patches are defined as the different plant communities or land use types found on the managed area or area to be restored. Classify and map the patches according to type (for example, forest, wetland, prairie, developed area), patch quality, and risk of invasion. Patch quality is measured against the restoration goals. If a goal is to re-create presettlement plant and animal communities similar to undisturbed reference sites, the highest quality patches are those that correspond to the reference site in terms of species composition and diversity. In general, areas where native plants of desired species are present and reproducing are the most valuable habitats, and the most likely areas to be recolonized by natives once exotics are removed (Table 1). Areas where exotics are just becoming established are of intermediate quality. These are a second priority for prevention of exotic increase and spread (Sauer 1998). The lowest-quality patches are those already dominated by invasive species.

Patches with the greatest risk of invasion are those containing habitat that is most suitable for invasive species. For example, areas with breaks in the natural plant cover are most susceptible to invasion, as are areas near sources of invasive propagules. Changes in environmental factors, such as light levels, nutrient levels or runoff, may enhance invasion probability. Look for habitat features that may affect the movement or activities of dispersal vectors, such as trees that are perches for birds that scatter seeds (With 2002).

Evaluating plant invasibility is not, however, a one-time task. It requires constant review because conditions change over time. The invasiveness of a plant species may vary with geography and site characteristics, and previously non-invasive species may show sudden population increases and geographical expansion. Changing environmental conditions, such as increased temperatures over a period of years, may stimulate certain species to increase their reproductive rates and become invasive (Kowarik 1995). This is a serious concern as global warming looms.

Surroundings

Next, place patches in their spatial surroundings. Identify the vegetation of surrounding areas, both areas directly adjacent to the managed area and areas connected to the managed area by corridors. Look for populations of potentially invasive species, especially in areas recently disturbed by logging, mining, and building or road construction. Land use in surrounding areas may alter ecological processes, especially hydrology, in the managed area. Keep a close watch on areas where sediment has been deposited because sediment is often a source of new propagules. If the surrounding land supports invasive species, there will be a constant influx of propagules onto the restoration and the risk of invasion will be high (Table 2). In contrast, if surrounding areas support native communities, these areas may be sources of seeds and native animal colonizers, such as pollinators, thereby reducing the invasion risk to adjacent restored areas.

Edges and Corridors

Next, identify the edges and corridors that connect the restoration with its surroundings. Edges are present wherever two types of land use or two plant communities come into contact. Corridors, meanwhile, connect two communities or land-use types. Propagules of invasive species may enter the managed area at its edges or travel along corridors directly into the restoration. Edges may have high levels of disturbance and high light levels that allow invasive populations to become established. Streambanks, roads and powerline corridors often form both edges and

Table 1. Evaluating patch quality

Patch Quality	Patch Features
High	Native species present and reproducing; exotic species absent
Medium	Native species present and reproducing; exotic species becoming established
Low	Exotic species dominant; native species not reproducing

Table 2. Evaluating risk of invasion to patches

Invasion Risk	Features of Patch, Surroundings and Edges
High	Invasives established on surrounding areas; propagules entering; change in disturbance regime in patch
Medium	Invasives established in area, but managed area is protected by edge or buffer zone
Low	No invasives in surrounding areas; no new disturbance in patch

corridors. In Oregon, Parendes and Jones (2000) found high levels of invasive species along roads in a coniferous forest both on roads that had been abandoned 20 to 40 years before the study and along more recently disturbed roads.

Edges may also act as barriers to invasion. For example, many invasive propagules are unable to pass through an intact forest edge even when there are no leaves on the trees. To determine whether an edge is allowing passage of invasive propagules, compare native and invasive plant populations on both sides of the edge. Within the patch, compare plant populations near the edge to interior populations. If there are more invasives near the edge than far from it, next determine whether the invasives near are becoming established and reproducing. If so, the edge may be a high-priority area for invasive removal and native replanting.

Streamside and riverside corridor areas are frequently disturbed under natural conditions, although natural disturbances are frequently changed by human intervention outside the areas being restored. In these latter cases, stream and riverbanks may become dominated by species that were carried downstream and then germinated on the bare soil exposed after flooding. These plants may invade and displace other species growing further from the water. For example, Russian olive (*Elaeagnus angustifolia*) in the western United States has expanded its populations from disturbed riparian zones into riparian woodlands and uplands and has invaded mature cottonwood groves. Likewise, purple loosestrife (*Lythrum salicaria*) may become established along dikes and canals with fluctuating water levels, and from there invaded less disturbed wetlands (D'Antonio and others 1999). As with edges, look for invasive species populations near natural and human-made corridors and determine whether the invasives are reproducing. If so, protect the adjacent restored patches by managing the invasive species on the edges.

Evaluating Exotic Plant Species

Once patches, surroundings and edges have been mapped, the next step is to evaluate the interactions of non-native and native species present on or near the protected area in light of your restoration goals. Although these goals will most likely be met by native species, non-native species may also play positive ecological roles. For example, the fruits of Russian olive have high value for wildlife, the flowers supply nectar for insects, and the trees supply cover and nesting sites for birds (Brock 1998). At the very least, non-native weeds may be covering the ground and reducing the chances of invasion by species that are more difficult to remove.

Some species with no apparent positive ecological roles are invasive; some are merely weedy. Weeds thrive in disturbed habitats and their populations tend to decrease as succession proceeds. Invasive species are able to invade well-established native plant communities even when there is no obvious stress or disturbance to the community, and their populations tend to increase to the exclusion of native plants (Packard and Ross 1997). For example, prairie remnants sometimes contain native weeds, including daisy fleabane (*Erigeron strigosis*), annual ragweed (*Ambrosia artemisiifolia*), and common cinquefoil (*Potentilla simplex*) and exotic weeds, such as dandelion (*Taraxacum officinale*), common mullein (*Verbascum thapsus*), and Queen Anne's lace (*Daucus carota*). In restored sites, these species eventually die out as the restoration develops (Packard and Ross 1997), whereas leafy spurge (*Euphorbia esula*), which is invasive in intact prairies, will not decrease as the restoration matures and will require applications of herbicide before it is displaced.

Many books, articles (for example, Luken and Thieret 1997, Ricciardi and others 2000), and Web sites (for example, the Bugwood Network [www.invasive.org] and the Northern Prairie Wildlife Research Center [www.npwrc.usgs.gov/resource/othrdata/exoticab/exoticab.htm]) describe and illustrate known invasive species. These references provide vital information about a plant's biological characteristic and invasive potential. In some cases, field studies may be needed to determine whether an exotic species is having a negative effect on a community.

The National Research Council (2002) has developed guidelines for predicting whether a given plant species is potentially invasive. They found that invasive plants have a variety of common biological characteristics: 1) long flowering and fruiting periods that increase seed production and dispersal, 2) rapid reproductive maturity, 3) seeds that remain dormant in the seedbank until favorable conditions occur, and 4) efficient use of light, water, and soil or air-deposited nutrients. The council also noted that plants with better-developed root systems than native species, species that produce more nectar or more fruit than natives, and those that produce germination-inhibiting chemicals may be potentially invasive.

Deciding Whether to Manage Invasive Species

When harmful invasive species have been identified, land managers need to estimate the resources required to initiate management practices and maintain them indefinitely. They should consider all the possible effects of invasive control activities, including the costs of replanting native propagules into weeded areas, a restoration step and cost that is often overlooked.

Hiebert and Stubbendieck (1993, also Hiebert 1997) developed a scored protocol for the U.S. National Park Service to prioritize exotic plant species for management purposes. Their protocol evaluates both the significance of the threat each species poses to native communities (serious, lesser) and the feasibility of controlling the species (difficult or easy to control) for any site (Figure 2). They calculate threat by assigning points to measures of species abundance, the innate ability of the species to invade undisturbed and disturbed areas, the species' reproductive and competitive abilities, and the longevity of its seedbank. Feasibility of control is calculated according to the effectiveness, potential side effects, and cost of possible control measures. The urgency of control (whether delay in action will result in a large, moderate or small increase in the effort required for successful control) is an additional consideration. For example, leafy spurge (*Euphorbia esula*), common buckthorn (*Rhamnus cathartica*), and smooth brome (*Bromus inermis*) pose severe threats to the native plant communities at Pipestone National Monument in western Minnesota according to their ability to invade intact natural communities, their high reproductive rates (both from seed and vegetative reproduction and for buckthorn, resprouting when cut) and their fast dispersal and relatively large populations on the natural area. Managers at Pipestone have made the control of leafy spurge their greatest priority because the cost of delayed action would be highest for this species (Table 3).

Table 3. Exmples of weed species found at Pipestone National Monument (MN) ranked according to degree of threat and ease of control (from Hiebert and Stubbendieck 1993). Urgency rankings are indicated in parentheses.

	Feasibility of control	
Degree of Threat	**Hard to Control**	**Easy to Control**
Serious threat	leafy spurge (high) common buckthorn (medium) smooth brome (medium)	no species in this category at Pipestone NM
Lesser threat	Common plantain (low) Common dandelion (low)	dame's rocket (low) pineapple weed (low)

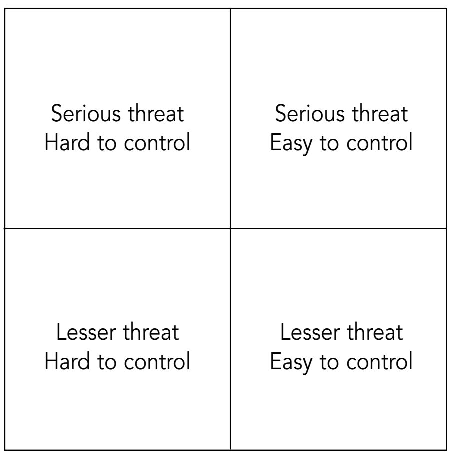

Figure 2. This diagram shows the four potentialities of an invasive plant related to its level of threat to a native plant community (serious or lesser) and the feasibility of control (difficult or easy). Categorizing invasive plants using this scheme can help restorationists and land managers when they are developing priorities for invasive species control and restoration.

Common plantain (*Plantago major*), pineapple weed (*Matricaria matricariodes*), and common dandelion (*Taraxacum officinale*) also have high reproductive rates at Pipestone, but they do not tend to invade undisturbed areas, so the managers consider them a lower threat.

In general, experience has shown that restorationists should attempt to eradicate or at least reduce a non-native species when it has a potential impact on a threatened or endangered species. This is especially important if the non-native species is known to be invasive elsewhere and/or appears to be well adapted to any disturbance or changed condition that has recently been introduced to the ecosystem (Huenneke and Thomson 1995). Species that increase sedimentation in aquatic systems, increase fire probability and intensity, or alter the soil and litter layer chemically or physically may enhance invasion by other exotics while reducing the probability of reestablishment by native species.

Prioritizing Areas to Restore and Protect

Once the worst species have been identified, the most vulnerable parts of the managed area have been located, the cost of control has been estimated, and the consequences of not managing have been evaluated, the next step is to decide where to begin. I suggest starting with the high quality patches that are at a high risk of invasion (Tables 1 and 2). Restorationists should protect these patches from invasion by 1) reducing the inflow of invasive propagules, 2) strengthening the edges, and 3) removing invasives and replanting natives in the surrounding areas. As resources allow, the focus can be shifted to protecting and restoring patches of lower quality and those at lower risk.

Monitoring

As restoration progresses, restorationists need to monitor native and invasive plant populations in the managed area to determine whether treatments are having the desired effects. The most informative and useful monitoring programs require careful planning, including statements of monitoring goals, preliminary sampling, replication of samples, and statistical analysis of results (Morrison 1997). The idea is to match monitoring methods with

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restoration goals and objectives. For example, if a goal is to increase native species richness, land managers must determine an efficient way to measure whether richness is increasing or not. They must also develop a format for recording observations that will be consistent regardless of who is making the observations. Obviously, trained botanists and ecologists can perform this kind of work, but experienced volunteers, if given proper training and the right kind of recording format, may also be able to make these observations (Holloran 1996, Brown and others 2001). Global positioning systems with mapping software are very helpful in either case (Carpenter and others 2002). Observations should be repeated on a regular schedule, recorded in a consistent format, and evaluated regularly. This process will involve returning to the original base map and records and again determining and mapping the areas occupied by reproducing native plants and those that contain undesired species. These maps sets can be used to compare the plant communities in treated areas with those of untreated areas and to evaluate the success of treatments. Managers should note any new invasions and be prepared to change management practices if they are not working.

Can Restorations Be Invasive-Proof?

The idea that established restorations will be free from invasion by unwanted species is likely mistaken. So many varying biotic and abiotic factors influence plant communities over time that there is no single factor that controls resistance to invasion.

So what can we do to at least attempt to invasion-proof restorations? The invasion or colonization process requires dispersal of the invading species or its propagules onto the site, seed germination followed by establishment of individuals, their persistence and reproduction, and the spread of the population. Interference with any stage can reduce the risk of successful invasion. I see three basic approaches to stopping or slowing the invasion process: 1) preventing the entry of invasive propagules, 2) preventing the germination and establishment of invasive species, and 3) restoring and maintaining natural processes.

Preventing Entry of Invasive Propagules

"First, do no harm." Hippocrates' advice to doctors is frequently extended to restorationists (Packard and Ross 1997). Land managers should avoid using potentially invasive species for erosion control or other reasons, and should work with adjacent landowners who have planted or are thinking about planting invasive species, such as crown vetch (*Coronilla varia*), birdsfoot trefoil (*Lotus corniculatus*), and reed canarygrass (*Phalaris arundinacea*). Non-native seeds can enter natural areas and restorations as contaminants of native seeds, in straw bales and other mulching materials, and in fill and topsoil. Many commercial wildflower seed mixes contain undesirable species, such as dame's rocket and Queen Anne's lace. Even nurse plants need to be scrutinized to determine whether they will become competitors for nutrients and impede rather than facilitate the establishment of the desired species (Marquez and Allen 1996).

As noted earlier, edges and corridors are likely entry points for exotic propagules. As a result, land managers should reduce edges and minimize traffic through valuable areas. Visitors' and workers' feet and vehicles, prairie grazers (including riding horses) and implements may carry seeds, as do birds, wind and water. To reduce entry of unwanted seeds into forests, restorationists and land managers should "seal" the forest edge by planting multilayered vegetation. This barrier will reduce the penetration of wind-dispersed seeds into the forest interior and will keep light levels low, preventing the establishment of some weedy species (Sauer 1998).

Preventing Establishment of Individual Invasive Plants

There is little doubt that invasive plants are most common where natural disturbance regimes have been altered. Restoration, however, often requires disturbance including physical, chemical, and biological modification of managed areas (Berger 1993). Such disturbances may increase invasive plant populations by eliminating predators or herbivores, by removing previously established plant species and reducing competition, stimulating germination of invasive plants, and altering resource levels to favor invasive species (D'Antonio and others 1999). Restorations are typically most vulnerable to invasion when there is a change in the disturbance regime or a new disturbance, especially when previously covered soil becomes exposed. For example, Packard (1997) points out that the first controlled burn of a previously unburned site may stimulate rapid growth of existing small populations of aggressive species, such as reed canarygrass, purple loosestrife and teasel (*Dipsacus* spp.) on wet sites, leafy spurge in uplands, and garlic mustard in woodlands. Cutting and herbiciding of brush in woodlands also opens space for invasive species.

Some negative effects of disturbance can be minimized by predisturbance site preparation. Packard suggests eliminating aggressive exotics and interseeding with native species before any burning is done. In forest restorations, where tree seedlings are planted, Thompson (1992) reports that control of grasses, such as smooth brome and fescue, is important during the first three to five years after planting or until tree seedlings are tall or dense enough to suppress competition. Ashby (1987) notes that forest restoration must be done in stages because many understory herbs will not survive until the tree canopy fully develops. He suggests planting shrubs before the tree canopy closes to provide more shade and to deter the establishment of unwanted invasives.

Perhaps the most important practice is to remove known invasive species while their populations are small. Dense infestations of garlic mustard, for example, probably cannot be eradicated on some sites, although hand weeding of small areas may prevent its establishment (Anderson and others 1996, McCarthy 1997).

Restoring Natural Processes

When invasive species have become established due to changes in natural processes, restoration of these processes may deprive invasives of their competitive advantage and allow natural recovery of native populations (Randall and others 1997). Seed germination occurs in response to specific environmental conditions, such as fire in some prairie and savanna species (Keddy and others 1989) and flooding in some riparian species (Sher and others 2002). Germination of seeds in wetlands may be manipulated in some cases by altering soil moisture conditions (van der Valk and Pederson 1989).

Limiting factors to any plant population typically include light, water, nutrients, competition, and predation. Low nutrient levels usually reduce the competitive ability of invasives relative to natives, whereas fertilization of sites to be revegetated frequently leads to the development of highly productive plant communities of low species richness (Luken 1990). Damage by biological control agents and shading by native species may act together to reduce the competitive ability of invasives.

Future Prospects

The introduction of non-native plant species will probably continue to increase as international travel and commerce become more common and human-caused disturbances increasingly alter natural conditions (Mooney and Hobbs 2000). There is cause for hope, however, as new methods for preventing and controlling plant invasions become available, and as the general public becomes more aware of the threats that invasive species pose to their well-being and that of the environment.

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References

Anderson, R.C., S.S. Dhillion and T.M. Kelley. 1996. Aspects of the ecology of an invasive plant, garlic mustard (*Alliaria petiolata*), in central Illinois. *Restoration Ecology* 4(2):181-191.

Ashby, W.C. 1987. Forests. Pages 89-108 *in* W.R. Jordan, III, M.E. Gilpin and J.D. Aber (eds.), Restoration ecology: A synthetic approach to ecological restoration. Cambridge, England: Cambridge University Press.

Berger, J.J. 1993. Ecological restoration and nonindigenous plant species: A review. *Restoration Ecology* 1:74-82.

Brock, J.H. 1998. Invasion, ecology and management of *Elaeagnus angustifolia* in the southwestern United States of America. Pages 123-136 *in* U. Starfinger, K. Edwards, I. Kowarik and M. Williamson (eds.), Plant invasions: Ecological mechanisms and human responses. Leiden, The Netherlands: Backhuys.

Brown, W.T., M.E. Krasny and N. Schoch. 2001. Volunteer monitoring of nonindigenous invasive plant species in the Adirondack Park, New York, USA. *Natural Areas Journal* 21:189-196.

Cairns, J., Jr. 1993. Ecological restoration: replenishing our national and global ecological capital. Pages 193-208 *in* D.A. Saunders, R.J. Hobbs and P.R. Ehrlich (eds.), Reconstruction of fragmented ecosystems: Global and regional perspectives. Chipping Norton, NSW, Australia: Surrey Beatty & Sons.

Carpenter, A.T., T.A. Murray and J. Buxbaum. 2002. Inventorying and mapping invasive plants. *Natural Areas Journal* 22:163-165.

D'Antonio, C., T.L. Dudley and M. Mack. 1999. Disturbance and biological invasions: Direct effects and feedbacks. Pages 413-452 *in* L.R. Walker (ed.), Ecosystems of disturbed ground. Amsterdam: Elsevier Scientific Publications.

D'Antonio, C. and L.A. Meyerson. 2002. Exotic plant species as problems and solutions in ecological restoration: A synthesis. *Restoration Ecology* 10:703-713.

Hiebert, R.D. 1997. Prioritizing invasive plants and planning for management. Pages 195-212 *in* J.O. Luken and J.W. Thieret (eds.), Assessment and management of plant invasions. New York: Springer-Verlag.

Hiebert, R.D. and J. Stubbendieck. 1993. Handbook for ranking exotic plants for management and control. Natural Resources Report NPS/NRMWRO/NRR-93/08. U.S. Department of the Interior. Denver, Colorado: National Park Services. www.npwrc.usgs.gov/resource/2000/aprs/APRS.HTM.

Holloran, P. 1996. The greening of the golden gate: Community-based restoration at the Presidio of San Francisco. *Restoration and Management Notes* 14:112-123.

Huenneke, L.F. and J.K. Thomson. 1995. Potential interference between a threatened endemic thistle and an invasive non-native plant. *Conservation Biology* 9:416-425.

Keddy, P.A., I.C. Wisheu, B. Shipley and C. Gaudet. 1989. Seed banks and vegetation management for conservation: Toward predictive community ecology. Pages 347-363 *in* M.A. Leck, V.T. Parker and R.L. Simpson (eds.), Ecology of soil seed banks. San Diego, California: Academic Press.

Kowarik, I. 1995. Time lags in biological invasions. Pages 15-38 *in* P. Pysek, K. Prach, M. Rejmanek and M. Wade (eds.), Plant invasions: General aspects and special problems. Amsterdam: SPB Academic Publishing.

Luken, J.O. 1990. *Directing ecological succession*. London: Chapman and Hall.

Luken, J.O. and J.W. Thieret, eds. 1997. *Assessment and management of plant invasions*. New York: Springer-Verlag.

Marquez, V.J. and E.B. Allen. 1996. Ineffectiveness of two annual legumes as nurse plants for establishment of *Artemisia californica* in coastal sage scrub. *Restoration Ecology* 4:42-50.

McCarthy, B.C. 1997. Response of a forest understory community to experimental removal of an invasive nonindigenous plant (*Alliaria petiolata, Brassicaceae*). Pages 117-130 *in* J.O. Luken and J.W. Thieret (eds.), Assessment and management of plant invasions. New York: Springer-Verlag.

Mooney, H.A. and R.J. Hobbs, eds. 2000. *Invasive species in a changing world*. Washington, D.C.: Island Press.

Morrison, M.L. 1997. Experimental design for plant removal and restoration. Pages 104-116 *in* J.O. Luken and J.W. Thieret (eds.), Assessment and management of plant invasions. New York: Springer-Verlag.

National Research Council. 2002. *Predicting invasions of nonindigenous plants and plant pests*. Washington, D.C.: National Academy Press.

Packard, S. 1997. Interseeding. Pages 163-191 *in* S. Packard and C.F. Mutel (eds.), The tallgrass restoration handbook for prairies, savannas, and woodlands. Washington, D.C.: Island Press.

Packard, S. and L.M. Ross. 1997. Restoring remnants. Pages 63-88 *in* S. Packard and C.F. Mutel (eds.), The tallgrass restoration handbook for prairies, savannas, and woodlands. Washington, D.C.: Island Press.

Parendes, L.A. and J.A. Jones. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews experimental forest, Oregon. *Conservation Biology* 14:64-75.

Pimental, D., L. Lach, R. Zuninga and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience* 50:53-65.

Randall, J.M., R.R. Lewis III and D.B. Jensen. 1997. Ecological restoration. Pages 205-219 *in* D. Simberloff, D.C. Schmitz and T.C. Brown (eds.), Strangers in paradise: Impact and management of nonindigenous species in Florida. Washington, D.C.: Island Press.

Ricciardi, A., W.W.M. Steiner, R.N. Mack and D. Simberloff. 2000. Toward a global information system for invasive species. *BioScience* 50(3):239-244.

Sauer, L.J. 1998. *The once and future forest: A guide to forest restoration strategies*. Washington, D.C.: Island Press.

Sher, A.A., D.L. Marshall and J.P. Taylor. 2002. Establishment patterns of native *Populus* and *Salix* in the presence of non-native *Tamarix*. *Ecological Applications* 12:760-772.

Society for Ecological Restoration Science and Policy Working Group (SER). 2002. *The SER Primer on Ecological Restoration*. www.ser.org/.

Thompson, J.L. 1992. *Prairies, forests and wetlands: The restoration of natural landscape communities in Iowa*. Iowa City: University of Iowa Press.

van der Valk, A.G. and R. L. Pederson. 1989. Seed banks and the management and restoration of natural vegetation. Pages 329-346 *in* M.A. Leck, V.T. Parker and R.L. Simpson (eds.), Ecology of soil seed banks. San Diego, California: Academic Press.

Williams, C.E. 1997. Potential valuable ecological functions of nonindigenous plants. Pages 26-24 *in* J.O. Luken and J.W. Thieret (eds.), Assessment and management of plant invasions. New York: Springer-Verlag.

With, K.A. 2002. The landscape ecology of invasive spread. *Conservation Biology* 16: 1192-1203.

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