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20

Controlling Cheatgrass in Ponderosa Pine and Pinyon-Juniper Restoration Areas

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Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability….Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science & Policy Working Group 2004).

In the southwestern United States, most ponderosa pine forests have been degraded during the last 150 years. Many ponderosa pine areas are now dominated by dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-intensity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. By allowing natural processes, such as fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

The ERI Working Papers series presents findings and management recommendations from research and observations by the ERI and its partner organizations. While the ERI staff recognizes that every restoration project needs to be site specific, we feel that the information provided in the Working Papers may help restoration practitioners elsewhere.

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Cover: A monotypic stand of cheatgrass *(Bromus tectorum)* colonized disturbed areas two years after burning and thinning restoration treatments at Mt. Trumbull in northwest Arizona. *Photo courtesy of Chris McClone*

Introduction

Cheatgrass (*Bromus tectorum*) is widespread throughout western North America and is a significant concern for land managers conducting restoration treatments in southwestern ponderosa pine and pinyon-juniper forests. It is common on a few restoration treatment areas in northern Arizona, on severely burned mature/old growth pinyon-juniper sites at Mesa Verde National Park in southwestern Colorado (Floyd et al. 2006), throughout wildfire areas in Zion National Park in southern Utah (U.S. National Park Service 2007), and on areas consumed by wildfire in northern Arizona (Sieg et al. 2003). There is concern that cheatgrass populations may expand further with an increase in the scale and frequency of restoration treatments in southwestern ponderosa pine and pinyon-juniper ecosystems (Pierson and Mack 1990b).

Researchers have demonstrated that restoration treatments (i.e., thinning and burning) in ponderosa pine ecosystems increase both the diversity and abundance of invasive plant species (Griffis et al. 2001, Dodson 2004, Wienk et al. 2004). However, the exact nature of this relationship is still uncertain. For example, in a thin/burn treatment in northwestern Arizona, ERI researcher, Chris McGlone and his colleagues observed little correlation between different levels of forest thinning and changes in cheatgrass frequency, suggesting that while some level of forest thinning must occur in order to provide the right conditions for cheatgrass invasion, other factors, such as weather conditions, may be equally important (McGlone et al. unpublished). While this study sheds important light on the topic of cheatgrass invasion in restored ponderosa pine sites, it is only one study and, as Keeley and his colleagues (2006) point out, long-term studies are needed to determine whether management practices, such as thinning and/or burning, provide an opportunity for cheatgrass to gain a foothold that will allow it to persist for a long time.

The goals of this working paper are to provide land managers with: 1) basic information about cheatgrass, 2) discuss the effects that have been observed when it invades an area, 3) summarize methods that have been used to control cheatgrass, and 4) make recommendations for reducing the invasion and spread of cheatgrass in ponderosa pine and pinyon-juniper restoration treatments.

The Characteristics of Cheatgrass

Cheatgrass is a non-native, annual grass first introduced into the western United States in the late 1880s. Now found throughout the United States, Mexico and Canada, it is also known as downy brome, downy chess, early chess, drooping brome, downy cheat, cheatgrass brome, slender chess, downy bromegrass, military grass, broncograss, and Mormon oats (Upadhaya et al. 1986).

Cheatgrass is usually a winter annual grass, but it can assume the characteristics of a spring annual when limited moisture during the fall inhibits its germination (although spring-germinated plants tend to be less vigorous and have low reproduction) (Mosley et al. 1999, Zauhar 2003). It typically germinates in early fall, and overwinters as small seedlings (Mosley et al. 1999). The stems of the seedlings and mature plants are bright green, erect, slender, and hairless or slightly soft-hairy. The leaves, however, are conspicuously hairy, hence the alternate common name, downy brome. The leaves also have a distinctive curly form (Figure 1).

Figure 1.

Figure 1: A cheatgrass seedling pulled in late October from a dry, gravelly site in Flagstaff, Arizona. Note the fiberous roots, prominent midrib in the leaves, the twisted nature of several leaves, and the red/purple markings at the base of the stem.

Seedlings grow quickly in the spring and often become mature and set seeds before most other species. Cheatgrass is extremely successful at using moisture and nutrients from the upper layers of the soil, partly because it starts growing earlier than most other species (Upadhaya et al. 1986, WWIRC 2007). Plants

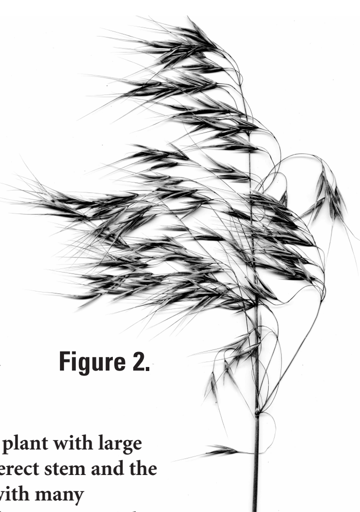

Figure 2.

Figure 2: Mature cheatgrass plant with large seedhead. Note the slender, erect stem and the drooping panicles covered with many spikelets. Each spikelet produces two to eight seed-producing florets.

typically grow 20-24 inches tall, and have a finely divided, fibrous root system that typically reaches a depth of less than 6 inches, although it may reach about 12 inches in some situations. When environmental conditions are poor and/or when grazing animals crop it, cheatgrass plants can still flower and produce viable seed even though they may only be 2-4 inches tall. Cheatgrass is considered to be highly competitive under drought conditions (Melgoza et al. 1990).

Cheatgrass reproduces only by seed (Mosley et al. 1999). Plants produce seed heads in late April to early May, which mature in mid- to late-June (Upadhaya et al. 1986) (Figure 2). During seed ripening, cheatgrass plants turn purple and then brown as they mature and senesce. Seeds begin to fall shortly after the purple stage is reached (Zouhar 2003). Seeds are viable when the fruits have barely started to turn purple and are still mostly green (Zouhar 2003). Cheatgrass seeds remain viable for two to five years in the soil or when stored dry within bales of straw or hay (Mosley et al. 1999).

Figure 3.

Figure 3. Cheatgrass spikelets have two or three uneven-sized glumes. Note the long, straight awns at the end of the glumes. These awns and other spikelet parts adhere to clothing, footwear and animals, aiding in the spread of cheatgrass.

Cheatgrass plants produce many seeds, depending on the environment and the spacing and size of the plants. Individual plants growing in high densities may produce about 25 seeds each, while a large, open-grown plant can produce about 400 seeds (Zouhar 2003). Cheatgrass seeds (Figure 3) are easily dispersed because the awned spikelets readily attach to clothing, footwear, animals, machinery, and vehicles.

While cheatgrass produces many seeds, its plant density is really defined by the number of available sites in the seedbed capable of supporting germination (Young and Evans 1985). Cheatgrass seeds require a cover of soil, litter or mulch to germinate in drier environments (Young and Evans 1978, Mosley et al. 1999). However, Keeley and McGinnis (2007) report that cheatgrass was inhibited by a dense surface layer of ponderosa pine needles in low-elevation forests in Kings Canyon National Park in southern California.

Cheatgrass is usually found in disturbed shrub-steppe areas, rangeland that has been overgrazed, road edges, and other heavily disturbed areas, such as abandoned fields. It has also been found in undisturbed areas as well (Carpenter and Murray 1999). In all plant communities, disturbance from livestock grazing and fire seem to be prerequisite for cheatgrass colonization (Warg 1938, Stewart and Young 1939, Young and Evans 1978, Knapp 1996).

Some researchers (Warg 1938, Hulbert 1955) have reported cheatgrass establishment in lower-elevation forests dominated by ponderosa pine *(Pinus ponderosa)*, but these communities are generally considered to be less vulnerable to invasion than shrubland and grassland ecosystems (Pierson and Mack 1990a, 1990b; Pierson et al. 1990). This is particularly true for forests where fire suppression has effectively excluded fire for much of the twentieth century (Keeley et al. 2006, cited in Keeley and McGinnis 2007). However, following disturbance, cheatgrass is capable of invading drier forests because logging, burning, and herbicide treatments are known to encourage cheatgrass invasion (McDonald and Everest 1996, Pierson and Mack 1990a, 1990b, Crawford et al. 2001, Keeley et al. 2003). In pinyon-juniper ecosystems, cheatgrass tends to be more invasive on southern and western exposures than on northern exposures (Zouhar 2003).

Upadhaya et al. (1986) report that cheatgrass grows in areas receiving 6-22 inches of annual precipitation. Cheatgrass has been found growing on almost any soil, but has been reported to prefer course-textured soils. It does not grow well on extremely heavy or dry soils (Upadhaya et al. 1986).

Cheatgrass has been found at elevations up to 13,000 feet in the United States, but it does not flourish or form viable populations in the late-successional forest zones of the Intermountain region of western North America (Carpenter and Murray 1999). The inability of cheatgrass to establish persistent populations under dense, high-elevation forest canopies is attributed to: 1) its relatively shade-intolerant physiology, 2) the short growing season at high elevations, and 3) the role herbivores, such as elk and deer, can play by grazing cheatgrass, thus preventing it from maturing during the short growing season (Pierson and Mack 1990b). It should be noted, however, that founder populations will establish under solitary pinyon or juniper trees in the drier, warmer environments of the high desert.

Ecological Effects of Cheatgrass on Ponderosa Pine and Pinyon-juniper Ecosystems

In areas it has invaded, cheatgrass has been found to substantially change the local fire regime (Whisenant 1990), alter soil characteristics (Evans et al. 2001, Norton et al. 2004) and significantly reduce plant diversity (Mack 1981). Moreover, these changes have consequent cascading effects on wildlife species.

Shortened fire-return intervals and increased fire risk

Because cheatgrass complete its growth cycle more quickly than most plants, it dries early in the growing season and becomes highly combustible. These dry plants can then fuel wildfires, and, in some areas, their presence can greatly increase the length of the fire season (Keeley and McGinnis 2007). Because cheatgrass is widely recognized as being fire-adapted, increasing fire frequency favors its own establishment and spread (Ziska et al. 2005).

Carpenter and Murray (1999) report that cheatgrass has an important competitive advantage because of its ability to alter the frequency of fire. This effect is most evident in sagebrush steppe habitat where fire intervals are now significantly shorter due to cheatgrass (Mosley et al. 1999). At these greater fire frequencies, native shrubs and perennial grasses cannot recover and a cheatgrass monoculture develops after a few wildfire cycles. This monoculture further increases the frequency of fires and increases the dominance of cheatgrass in the area.

In pinyon-juniper woodlands, a dramatic increase in fire size and frequency has been observed as the cover of nonnative annuals, such as cheatgrass, increases (Zouhar 2003). Working in Nevada, Billings (1994) found that where fires have burned in a singleleaf pinyon-Utah juniper (*Pinus monophylla-Juniperus osteosperma*) woodland invaded by cheatgrass, the woodland is being replaced by great expanses of annual grassland, dominated by cheatgrass.

Zouhar (2003) reports that fire suppression and livestock grazing have contributed to the decline of perennial grasses, an increase in nonnative annuals such as cheatgrass, and an increase in shrubs and trees at many sites within pinyon-juniper woodlands. This has subsequently increased the number of large, high-severity fires and the resultant loss of pinyon and juniper trees. When cheatgrass is present in the understory with little or no perennial vegetation, removing pinyon and juniper trees usually leads to cheatgrass dominance (Zouhar 2003).

Fires in ponderosa pine forests, especially high-severity fires, can lead to cheatgrass invasion and dominance (Zouhar 2003). At Sequoia-Kings Canyon National Park, prescribed burning in ponderosa pine in the Cedar Grove section appears to have promoted a vigorous invasion of cheatgrass (Keeley 2001). Crawford et al. (2001) reported higher cover of cheatgrass on severely burned sites, compared to less severely burned sites, in ponderosa pine in Arizona. The presence of cheatgrass-dominated ecosystems adjacent to these dense forests is also likely to cause larger, more frequent, and more severe wildfires (Crawford et al. 2001).

Severe fire can remove the entire root of annual cheatgrass, killing the plants and resulting in bare soil exposed to erosion from wind and water. Cheatgrass seeds are susceptible to heat kill, but can survive fires of low severity if the entire topsoil layer is not consumed or if seeds are buried deeply enough to be insulated from the heat (Young 1991).

Displacing native vegetation

The tendency of cheatgrass to displace native vegetation is of particular concern in the western United States. This is especially true in sagebrush steppe habitat where cheatgrass has become the dominant plant community in many areas (WWIRC 2007).

Evans et al. (2001) found that burning cheatgrass changes the soil chemistry, leading to decreased nitrogen availability and altered plant species composition. In addition, mature cheatgrass plants add organic matter to the soil surface, thereby enhancing germination and establishment of young cheatgrass plants (Evans et al. 2001). Established cheatgrass has been found to interfere with both the growth and survival of native species, such as bluebunch wheatgrass (*Pseudoroegneria spicata*) (Harris 1967). Cheatgrass can displace both rare and common plant species, thus reducing the genetic diversity of native plants in invaded communities (Zouhar 2003). In a study at Canyonlands National Park in southeast Utah, Belnap et al. (2005) found that the invasion of cheatgrass resulted in a decrease in species richness and a species shift in plants, microarthropods, fungi, and nematodes.

Cascading effects on birds and mammals

Forest restoration treatments often result in an improved herbaceous community (Covington and Moore 1994), which can be beneficial to many wildlife species. For instance, Wightman and Germaine (2006) found that restoring or maintaining at least a 20% ground cover composed of grasses, forbs, and bare soil improved western bluebird (*Sialia mexicana*) habitat in ponderosa pine restoration treatments in northwestern

Arizona. Citing the work of other researchers (Murdoch et al. 1972, Haddad et al. 2001) who found a correlation between insect diversity and ground cover heterogeneity, Wightman and Germaine caution that monotypic invasive species, such as cheatgrass, could reduce the quality of ground cover conditions for western bluebirds by reducing the diversity of available insect prey.

While forest restoration treatments may improve conditions for some wildlife species, vegetation type conversion, like that produced by cheatgrass, can negatively affect some wildlife ranging from herbivores to carnivores, and reduce overall biodiversity (Brooks and Dyke 2001). Dellasala et al. (2004) report that the spread of cheatgrass into Idaho's Bird of Prey National Conservation Area has shortened fire-return intervals with cascading effects on the ecosystem, including the loss and fragmentation of shrub communities, changes in small mammal populations, and concomitant losses of falcons (*Falco* spp.), golden eagles (*Aquila chrysaetos*), and bald eagles (*Haliaeetus leucocephalus*).

Control of Cheatgrass

An effective cheatgrass management program needs to: 1) control existing populations by eliminating live plants; 2) prevent seed formation; 3) control seed germination and emerging seedlings; and 4) develop a management plan to deter re-infestation of cheatgrass (Zouhar 2003). Since cheatgrass reproduces entirely by seed, the key to controlling existing infestations is to eliminate new seed production and deplete the existing seedbank.

Methods that have been used to control cheatgrass include hand-pulling, mowing, grazing, burning, herbicides, and cumulative stress methods. Because most land managers are working with extensive acreages, we will not discuss hand-pulling (which can be effective on a small scale) or mowing (which is not generally effective at any scale). Although grazing is cited as a vector in the spread of cheatgrass, some research indicates that prescribed grazing may help control of cheatgrass, but only if done at the correct time and intensity. However, because the risk of spreading cheatgrass by grazing appears to outweigh the benefits, we recommend against the use of grazing to control cheatgrass and further suggest that, if feasible, managers defer grazing after restoration treatments for a minimum of three years.

Burning

In areas only partially infested with cheatgrass, burning is usually not recommended as a means of control (Carpenter and Murray 1999). Cheatgrass populations can rebound quickly after a fire and the temporary elimination of the native species will only give cheatgrass the opportunity to spread. Cheatgrass can invade recently burned sites from offsite seed sources, from contamination of native seeds spread in the area (Keeley et al. 2006), or from seed in the seedbank, even if plants are absent from the site at the time of the fire (Zouhar 2003). McClone et al. (unpublished) observed a lag time of two to five years after a prescribed fire before cheatgrass invaded burned sites.

Results of experiments in low-elevation ponderosa pine forests in Kings Canyon National Park on the interaction of cheatgrass and fire show that burning stimulates cheatgrass populations, regardless of whether it occurs in late spring or early fall (Keeley et al. 2006, Keeley and McGinnis 2007). Based on their work and a finding that indicates that pine needle litter has the potential to inhibit cheatgrass invasion, these researchers suggest that, where feasible, fire managers should consider fire frequencies that reduce serious fire hazard but do not increase plant invasions or cause long-term negative effects for the ecosystem.

Keeley and his colleagues (2006) suggest that burning larger areas may be another way to alter the invasive threat because small fire treatment patches have a larger perimeter-to-area ratio, making the burned area more vulnerable to invasion, whereas large burn patches have a smaller perimeter-to-area ratio, making the bulk of the burned area less susceptible to colonization from outside invaders, such as cheatgrass.

While burn patch size may be important when attempting to minimize the spread of cheatgrass, it is also important to consider the pattern of invasive plant distributions in the landscape (Keeley et al. 2006). For example, if forest patches are adjacent to open habitat, they are much more susceptible to invasion than forests surrounded by more closed forest (Keeley et al. 2003).

Young (1983) reports that burning cheatgrass may reduce germination rates, but may enhance seed production per plant. Bunting et al. (1987) and Rasmussen (1994) indicate that burning in the fall, followed by herbicide application before seed-set the following year can be used to reduce vigor and the seed-set rates of remaining cheatgrass plants. However, Carpenter and Murray (1999) recommend burning in late May or early June, after the plants have dried, followed by a reseeding effort.

Herbicides

Used either alone or together, repeated applications (every 2-5 years) of herbicide have been used to control cheatgrass (Zouhar 2003). The herbicides typically used include quizalofop (Assure II, Pilot Super, Targa D+, and Targa Super), paraquat (Gramaxone Extra), glyphosate (Roundup Pro, Rascal), imazapic (Plateau), atrazine (Aatrex, Aktikon, Alazine, and many other names), fluazifop-b-butyl (Fusilade 2000, Fusilade DX, Fusilade Five, Fusilade Super), sethoxydim (Poast, Tritex-Extra, and Vantage), and sulfometuron methyl (Oust Weed Killer and DPX 5648) (Mosley et al. 1999, Zouhar 2003). Sieg et al. (2003) indicate that these herbicides show promise, when integrated with reseeding programs that establish a competitive perennial plant community. Indeed, land managers at Zion National Park are currently using aerial applications of imazapic (and glyphosate, if cheatgrass has begun to grow) during the fall to control cheatgrass and other invasive annual grasses on thousands of acres of pinyon-juniper that were consumed by wildfires in 2006 and 2007 (U.S. National Park Service 2007). They are planning to follow these treatments with plantings of native grass and shrub species.

Timing of herbicide treatment and application methods vary depending upon the herbicide used. The Nature Conservancy's *Weed Control Methods Handbook* provides detailed information about many of the herbicides listed in this section. It can be found at: http://tncweeds.ucdavis.edu/handbook.html. One of the main concerns is applying an herbicide at times that will effectively control cheatgrass, but not harm existing, desirable vegetation. This is usually not a concern when working in monocultures of cheatgrass, but it may very well be in diverse forest openings.

Cumulative stress method

The "cumulative stress" method of controlling cheatgrass infestations is reported to provide lasting control of cheatgrass by implementing a combination of chemical control, physical control, vegetative suppression, and proper livestock management (if the land is grazed). This method is designed to keep the cheatgrass constantly under stress, reducing its ability to flourish and spread. A cumulative stress approach also provides a level of redundancy in situations where one type of treatment is not implemented or proves to be ineffective (Carpenter and Murray 1999).

For larger areas where herbaceous vegetation is dominated by cheatgrass, Carpenter and Murray (1999) suggest a two- to three-year combination of burning, herbicide application, and reseeding to control cheatgrass and revegetate the area with native vegetation. They suggest the following steps:

- Burn and re-seed the area with native perennial grasses during the first year. The following spring, apply herbicides (quizalofop, fluazifop, sethoxydim, glyphosate, or imazameth) before the seeded perennial grasses emerge in order to eliminate any cheatgrass that emerged from the seedbank after the burn.
- If necessary, apply the same herbicide early in the spring of the third year (prior to the emergence of native grass species) to control any new cheatgrass seedlings, and provide time for native grasses to establish.

Carpenter and Murray (1999) report that applying this series of treatments should control the cheatgrass, deplete the existing cheatgrass seed bank, and provide adequate time for perennial grasses to establish to the point where they can suppress any new cheatgrass invasions.

Recommendations for Cheatgrass Management Associated with Restoration Treatments in Ponderosa Pine and Pinyon-juniper Ecosystems

An inherent risk exists when carrying out restoration treatments in ponderosa pine and pinyon-juniper ecosystems because cheatgrass is known to respond to the disturbance associated with thinning and prescribed fire treatments. However, leaving unhealthy forest ecosystems completely untreated is not an effective solution. Thus, it is necessary to carefully plan and implement restoration treatments that assist in preventing severe wildfires and also help prevent the invasion of cheatgrass into previously unoccupied sites.

Below are a series of recommendations when implementing restoration treatments in ponderosa pine and pinyon-juniper forests. While it may not be possible to implement all of the recommendations listed below, we encourage land managers to strive to incorporate as many of them as possible in restoration treatment management plans, using a triage strategy as necessary.

- **Conduct a pre-treatment inventory** that includes randomized sampling and mapping of the restoration project area and adjacent lands to determine the distribution and severity of cheatgrass infestation as well as all other invasive species, such as diffuse knapweed (*Centaurea diffusa*) and dalmation toadflax (*Linaria dalmatica*). This is one of the most important steps managers can take when planning a restoration project. The information gained during the inventory will help managers to make sound decisions about the invasive species in the project area.

- **Prioritize treatment areas** after analyzing the pre-treatment inventory.

  a) Postpone restoration in areas with high levels of cheatgrass until control efforts have been in place long enough to significantly reduce their populations and the seedbank.

  b) Aggressively treat small infestations of cheatgrass prior to conducting restoration treatments because these treatments will likely be successful and will help curtail the spread of cheatgrass to other areas of the site.

  c) Ensure that heavy traffic areas, such as roads, staging areas and landings, have no cheatgrass present.

- **Minimize soil disturbance** by avoiding road building, tree removal, and unnecessary pile or prescribed burning, as much as possible. For instance, managers can take advantage of existing roads and use them as fire breaks during prescribed fire treatments rather than building new fire lines. Hand-piling slash is preferable to skidding and small, tall piles result in less disturbed soil than large, spread out piles.

- **Prevent the transfer of seeds to the restoration site** by washing the undercarriage of field vehicles. Avoid carrying mud on vehicles and have workers wear gaiters when walking through cheatgrass-infested areas.

- **Seed restoration project areas with native species.** Fast-growing native species, such as squirreltail (*Elymus elymoides*), may help slow the spread of cheatgrass. Thurber's needlegrass (*Achnatherum thurberianum*), western wheatgrass (*Pascopyrum smithii*), sand dropseed (*Sporobolus cryptandrus*), Sandburg bluegrass (*Poa secunda*), thickspike wheatgrass (*Elymus lanceolatus*), purple three awn (*Aristida purpurea*), and fourwing saltbrush (*Altriplex canescens*) have shown that they can reseed areas previously occupied by cheatgrass (Monson 1994 as cited by Zouhar 2003, Haile et al. 2006). The warm-season native grass, hilaria or James' galleta (*Hilaria jamesii*), has been observed to grow well in cheatgrass-infested areas of the Colorado Plateau whenever it can take advantage of warm, summer rains (Carpenter and Murray 1999).

  Seeding native perennial grasses into former cheatgrass-infested areas is usually necessary after burning, otherwise cheatgrass and other weeds will simply reestablish in the disturbed area (Carpenter and Murray 1999). When seeding does not occur, cheatgrass has been observed to return to pre-burn densities within a few years (Carpenter and Murray 1999).

  However, managers should recognize that native seed mixes may be contaminated with cheatgrass and other invasive species. Insist on clean, certified native seed from reputable seed dealers, and inspect seed bags when they arrive for cheatgrass seeds. Weigh the costs and benefits of using potentially contaminated seeds in areas where cheatgrass has not invaded. It may not be worth the risk of potentially introducing this and other invasive non-natives.

- **Minimize burn severity** when conducting prescribed fires. Burn slash piles with low-intensity, short-duration fires. High-severity fires can result in the loss of nutrients as well as seeds, microscopic plants, and mycorrhizae in the soil, reducing the chance of native plants to naturally colonize the site. Low-intensity prescribed fire results in fewer negative effects on the native understory. One means to help ensure that prescribed fire is of low intensity is to remove excess biomass created by the restoration thinning so that prescribed burning can be conducted within the natural range of variability.

- **Avoid burning during dry years when native plants can't recover as quickly.** Managers need to consider the likelihood of the recovery of native species after prescribed burning. If feasible, reschedule burning for years when native species are not stressed due to drought conditions.

- **Monitor after restoration treatments** and immediately treat cheatgrass infestations that begin to colonize an area. Monitoring after treatment is vital and should be done annually.

While cheatgrass is a significant problem in many lower-elevation ecosystems of the West, control of cheatgrass is still possible in the ponderosa pine and pinyon-juniper ecosystems. Awareness by managers of the presence of cheatgrass in and/or adjacent to restoration treatment areas is of foremost importance. Then, creation of an active and effective course of management can be determined and implemented.

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