

**The Effects of Non-herbicidal Methods of  
Invasive Plant Treatment on  
Wildlife, Fish, and Plants**

**A Specialist's Report prepared for the USDA Forest Service,  
Region 6, Invasive Plant EIS**

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**Prepared By: Shawna L. Bautista, Wildlife Biologist  
Linda Mazzu, Botanist  
Jan Robbins, Hydrologist  
Diana Perez, Forest Fisheries Biologist  
Lia Spiegel, Entomologist**

## **Non-herbicidal Methods of Invasive Plant Treatments**

### ***Introduction***

Invasive plants may be treated or controlled by a wide variety of methods and tools. The effects of herbicide use are discussed in separate reports, or in the body of the EIS. Non-herbicidal methods considered in this report include, manual, mechanical, fire, cultural, restoration and revegetation, and biological control. In some cases, the boundary blurs between methods. What is considered a cultural method by some may be considered simply revegetation by others.

Because this appendix may be used as a stand alone document, some of the information found in the EIS is repeated here. The first section describes the methods of non-herbicide control. It contains information from Chapter 3 and some additional examples of use in the field. The second section includes the environmental consequences; the majority of the second section is only found in this Appendix.

### **Description of the Methods**

#### ***Manual and Mechanical***

Manual and mechanical treatments physically remove and destroy, disrupt the growth of, or interfere with the reproduction of invasive plants. These treatments can be accomplished by hand, hand tool (manual), or power tools (mechanical); and include pulling, grubbing, digging, hoeing, tilling, cutting, mowing, and mulching of the target plants. Thermal techniques such as steaming, super heated water and hot foam are also considered as viable treatments.

Manual methods can be effective on small infestations if the entire root is removed. With new, small infestations, hand pulling can be the easiest and quickest method. Even larger populations, though, can be controlled with hand pulling if the workforce is available. The Bradley Method is one sensible approach to manual control of invasive plants (Fuller and Barbe, 1985). This method consists of hand weeding selected small areas of infestation in a specific sequence, starting with the best stands of native vegetation (those with the least extent of infestation) and working towards stands with the worst infestation.

Manual methods are usually not as effective for deep-rooted or rhizomatous<sup>1</sup> perennials such as leafy spurge where hand-pulling and hoeing often leave root fragments that can generate new plants. Hand-pulling or hoeing also disturbs the soil surface, which may increase susceptibility of a site to reinvasion by weeds (Brown et al., 2001; Duncan et al., 2001). Manual methods are labor-intensive and usually ineffective for the treatment of large, well-established infestations of perennial invasive plants with long term viable seed such as knapweeds (Brown et al., 2001). Local efforts where larger community support or funding for hand crews exists do show promise, if efforts can be sustained (Henry, 2004).

The Nature Conservancy reported success with the use of manual control. (Tu et al., 2001). Hand pulling by volunteers has successfully controlled *Centaurea diffusa* (diffuse knapweed) in the Tom McCall Preserve in northeast Oregon. Yellow bush lupine (*Lupinus arboreus*) was also controlled in coastal dunes in California by pulling small shrubs by hand. Larger shrubs were cut down with an ax, and re-sprouting was uncommon (Pickart and Sawyer, 1998). Hand pulling has also been fairly successful in the control of small infestations of *Centaurea spp.* (thistles), *Melilotus officinalis* (white and yellow clover), and *Lythrum salicaria* (purple loosestrife) at TNC preserves scattered across the country.

Manual tools such as the Weed Wrench ([www.weedwrench.com](http://www.weedwrench.com)) can be used on herbaceous plants that have a stem or bundle of stems strong enough to withstand the crush of the jaws. It has been used successfully to pull acacia (*Acacia melanoxylon*), buckthorn (*Rhamnus cathartica*), Russian olive (*Elaeagnus angustifolia*), multiflora rose (*Rosa multiflora*), willow (*Salix spp.*), tamarisk (*Tamarix spp.*), bush honeysuckles (*Lonicera spp.*), Scotch broom (*Cytisus scoparius*), French broom (*Genista monspessulanus*), and Brazilian pepper (*Schinus terebinthifolius*) at preserves across the mainland U.S. In Hawaii, the Weed Wrench has been used to pull Strawberry guava (*Psidium cattleianum*) and small saplings of Karaka nut (*Corynocarpus laevigatus*) from the Kamakou preserve on Molokai (Hawaii) (Tu et al, 2001).

Mowing or cutting is more effective on tap-rooted perennials such as spotted knapweed compared to rhizomatous perennials (Brown et al., 2001). Cutting or mowing plants can reduce seed production if conducted at the right growth stage. For example, a single mowing at late bud growth stage can reduce the number of seeds produced on spotted

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<sup>1</sup> Rhizomes are horizontally creeping, underground stems, which bear roots and leaves. Rhizomatous species tend to spread very quickly because of these growth structures.

knapweed (Watson and Renny, 1974). Mowing can also weaken an invasive plant's competitive advantage by depleting root carbohydrate reserves, but mowing must be conducted several times a year for consecutive years to reduce the competitive ability of the plant.

Oregon Department of Agriculture staff compared mowing and pulling mature plants to no treatment in two western Oregon spotted knapweed infestations. They applied one treatment annually at the optimum time for each of four consecutive years, and concluded that neither method was effective in reducing population density or cover. They recommend consideration of pulling and mowing only, where the goal is to contain spotted knapweed infestations or to suppress seed production (Isaacson et al., 1997).

Because invasive plants flower throughout the summer, it is difficult to time mechanical treatments to prevent flowering and seed production. Repeated mechanical treatment too early in the growing season can result in a low growth form that is still capable of producing flowers and seed (Benefield et al., 1999; Goodwin and Sheley, 2001).

Mechanical treatments on some rhizomatous weeds, such as leafy spurge, can encourage sprouting and result in an increase in stem density (Goodwin and Sheley, 2001).

Tillage methods are most effective for controlling tap-rooted invasive plant species on small acreages and level terrain, where infestations can be revisited on a regular basis to remove new germinants and resprouts over time. Tillage removes all vegetation and should be combined with seeding or planting of desirable species. Invasive plant seeds may remain viable in soil for several years (Davis et al., 1993; Selleck et al., 1962) and often may reinfest a tilled site, thus requiring continued follow-up treatments.

Mulching with plastic or organic materials can be used on relatively small areas (less than 0.25 acre), but will also stunt or stop growth of desirable native species. Mulching prevents seeds and seedlings from receiving sunlight necessary to survive and grow, and can smother some established invasive plants. Hay mulch was used in Idaho to reduce flowering of Canada thistle (Tu et al., 2001), but most rhizomatous perennial invasive plants cannot be controlled by this method or by shading because extensive root reserves allow regrowth through and around mulch or shade materials. A new mulch made from wood products is currently being tested by the Forest Service and shows promise as having equivalent or higher erosion control potential than regular straw mulch (Forest Concepts, 2004).

Thermal techniques are being tested or used with some success throughout Region Six by such agencies as Oregon Department of Transportation (ODOT), the Nature Conservancy and the Bureau of Land Management (BLM). ODOT has converted a mowing unit to a thermal heat unit for treating roadsides (Prull, personal communication, 2004). It has been most successful when used for maintenance treatments instead of initial treatments. The Nature Conservancy (Tu et al, 2002) tested the Eco-Weeder, an infrared technology device that uses the combustion of liquid gas to reach extremely high temperatures that place intense radiation directly on weeds to explode plant cells. The tool could be useful for small area treatments, especially on sidewalks, but the effectiveness on deep-rooted plants, sedges or rhizomatous grasses may not be as high. The Nature Conservancy also tested hot water pressure washers. The brand tested could apply hot water through a pressure nozzle with a wide spray or intense stream which would act as an injection device for below ground portions of plants. They found it effective on seedlings and annual plants within reach of the washer, but the effectiveness on plants with extensive underground roots or rhizomes would be less. Hot foam has been tested by the Nature Conservancy and used by the BLM effectively on puncturevine and slender false brome. Again, this technique is limited to the reach of the foam generator, but is an excellent non-chemical method. It is effective on seedlings and annuals and can be applied under weather conditions including wind and light rain. It has shown some success with perennials and an injection tool has shown some success with knotweeds (Fairchild, personal communication, 2004).

### ***Cultural Methods***

Cultural methods of invasive plant management are generally targeted toward enhancing desirable vegetation to minimize invasion. Common cultural treatments include planting or seeding desirable species to shade or out-compete invasive plants, applying fertilizer to desirable vegetation, and controlled grazing.

Native plant species usually do not out-compete invasive plants in disturbed habitat. Herbicide application after invasive plants have emerged, followed by tillage and drill seeding, can be effective in establishing desirable species on some sites (Sheley et al., 1999). This process, however, can lead to increased soil compaction (DiTomaso, 1999), and cannot be conducted on steep, remote, or rocky sites.

Seeding risks introduction of non-native and/or invasive species, but use of certified weed-free seed reduces this risk. The magnitude of the risk varies and may be

determined by seed source, cleaning practices, and other factors (see Site Restoration/Revegetation for more discussion).

Fertilization has had limited use in invasive plant management. It has been used on hawkweed species experimentally. Soluble nitrogen fertilizer applied after herbicide treatment could increase the competitiveness of perennial grasses and beneficial forbs. This method is most effective in pastures or rangelands where nitrogen levels are not high enough for optimum grass performance (Rinella and Sheley, 2002).

Grazing can be used to manage several invasive plant species successfully. Grazing animals prefer certain forage, and selective use of preferred forage can shift the competitive balance of plant communities (Crawley, 1983; Lukan, 1990). For example, goats and sheep have been used in various areas for controlling knapweed and leafy spurge. Controlled, repeated grazing of spotted knapweed by sheep has been found to reduce the number of 1 and 2-year old spotted knapweed plants within an infestation (Olson et al., 1997). Sheep have been shown to provide control for cheatgrass if grazed twice after winter rosettes have greened up (Mosley, 1996). Goats have been used to successfully control Himalayan blackberry using high stocking levels in small fenced areas (Peters, personal communication, 2004). Other species including gorse, bull and Canada thistle, scotch broom, yellow starthistle and perennial pepperweed are being grazed mostly by goats under different grazing strategies. Efforts for these species were combined with sheep grazing, herbicide treatment, biocontrols and planting competitive vegetation. The breed, sex, age of the animal and timing of grazing as it related to weed development and desired vegetation development were important factors in the design of an effective grazing prescription for these species (Peters, personal communication, 2004).

Appropriate grazing by animals preferring invasive species can shift the plant community toward more desired grasses (Lacey et al., 1989). Olson (1999) described three grazing strategies for managing weeds: (1) moderate grazing levels to minimize the physiological impact on native plants and to reduce soil disturbance; (2) intensive grazing to counteract inherent dietary preferences of cattle, resulting in equal impacts on forage species including weeds; and (3) multi-species grazing that distributes the impact on livestock grazing more uniformly among desirable and undesirable species.

Use of grazing animals as an invasive plant management tool must be based on selecting the appropriate grazer for the target invasive plant species. Managers must also determine when, how much, and how often to graze animals to have maximum impact on

the invasive plant with minimum impact on desirable plant species (Olson, 1999). Research has been occurring through the collaborative program BEHAVE (Behavioral Education for Human, Animal, Vegetation and Ecosystem Management) which includes partners from the Universities of Idaho, Utah, Arizona and Montana State University, and the National Wildlife Research Center. Studies on the relationships between animal condition and circumstance and their propensity to graze weedy plants is one focus as well as how age and body condition can affect consumption (Utah State University, 2004). Specific research tied to this program also includes focus on providing incentives such as molasses to get animals to eat weeds and supplying anti-toxins to counteract the negative effects of weeds on animals.

Grazing to manage weeds on roadsides, trailheads, and larger infestations on the forest is limited because of the difficulty of maintaining and managing the animals. A long-term commitment to small ruminant grazing is necessary for effective invasive plant management. Invasive plants can compensate quickly after the grazing pressure is removed because their seeds are long-lived in the soil, and because they can rapidly increase flower stem production once grazing pressure is removed (Olson et al., 1997 cited in Sheley et al., 1999).

Most often, though, a single method is not effective to achieve substantial control of a range weed. A Successful long-term management program should be designed to include combinations of mechanical, cultural, biological, and chemical control techniques (DiTomaso, 2000).

### ***Prescribed Fire Methods***

Use of prescribed burning for treatment of invasive plants has had limited application in Region Six. While fire is sometimes necessary to prompt the germination of some plant seeds, such as knobcone pine, fire can also cause sprouting of invasive plants, and create site conditions that are optimum for the spread of invasive plants. On the other hand, fire can sharply reduce the abundance of some species by preventing flower or seed set, destroying seeds, stimulating germination (for future seedling treatments), depleting carbohydrate reserves or killing perennating tissue (such as rhizomes, bulbs, or buds) (Rice, 2004). Fire can also be used to facilitate revegetation, increase herbicide efficacy, and remove litter to assist in emergence of desirable species (Rice, 2004). The weather, topography, and available fuel will determine the temperature and intensity of the prescribed burn this along with the timing of the treatment, largely determine how the burn impacts the vegetation and the abundance of particular species. Studies cited in a

literature review concerning the use of fire as a tool for controlling non-native invasive plants provides insight on such factors (Rice, 2004).

The effectiveness of fire as a tool is variable. Numerous research was cited in Rice (2004) regarding this effectiveness. Most studies focused on grassland habitats primarily in the Mid-west, but some valuable information for western states was included. For example, fire was used as a means to stimulate germination from a persistent seedbank of French and scotch broom species. This allows for follow-up treatments of seedlings over the two to three years needed for the new plants to develop seeds. Burning killed some seed and stimulated germination through scarification of other seeds in lab and field experiments (Bossard, 1993; 2000). This was more successful in drier conditions than wetter conditions (Parker, 2001).

The most effective fires for controlling invasive plant species are typically those administered just before flower or seed set, or at the young seedling/sapling stage. This timing may interfere with important growth periods for native species, though. Sometimes prescribed burns suppress an invasive species only as a side effect. In some cases, prescribed burns can unexpectedly promote other invasives, such as when their seeds are specially adapted to fire, or when they resprout vigorously which emphasizes the need for repeated burning (studies cited in Rice, 2004). Burning in the fall did show some success in reducing cover scotch broom in western Washington, but frequent burning would still be required (Tveten and Fonda, 1999).

In California's Dye Creek and Vina Plains Preserves, prescribed burns helped control the spread of invasive medusahead grass (*Taeniatherum caput-medusae*). California's Lassen Foothills Project also reported good success with >95 percent mortality of medusahead and yellow starthistle (*Centaurea solstitialis*) following prescribed burns (Tu et al, 2001).

Many prescribed burn programs are designed to reduce the abundance of certain native woody species that spread into unburned pinelands, savannas, bogs, prairies, and other grasslands. Repeated burns are sometimes helpful in controlling invasive plants. Herbicide treatments may be required as a follow-up treatment to kill the flush of seedlings that germinate following a burn.

Use of prescribed fire will also change soil chemistry and composition. Likewise, invasive seeds may germinate and some invasives will aggressively sprout after fire. Fire may encourage invasive plants even in communities that have evolved with fire. This

could happen because plant communities develop not in association with fire per se, but with a particular fire regime. If the fire regime has been altered, vulnerability to exotic plant invasion increases (Keeley, 2001). Given these confounding factors, a combination of treatments (such as fire and herbicide or fire and manual) would be most successful.

Flaming is a tool of use for controlling invasive plants. Flaming is done with the use of propane torches. Such torching tools have been available for agricultural and roofing use. They can be purchased as portable backpack units. Flaming destroys cell structure in the plant, therefore reducing its energy towards growth. It will kill most small weeds and will at least stunt or kill larger weeds, depending on their root system (Flame Engineering, no date). Flaming is limited to conditions that would be too moist to carry a fire. They are useful for spot burning single plants or a small population of plants with little disturbance to the surrounding vegetation (Tu et al, 2001).

Spot-burning using a propane torch has been used successfully by Jack McGowan-Stinski in several Michigan preserves. Jack reported killing >90 percent of baby's breath (*Gypsophila panicula*) seedlings with spot-burning. This method also kills most seedlings/saplings of buckthorn (*Rhamnus* spp.), where the adult plants have already been removed. In contrast, hand-pulling the seedlings requires more time and labor (Tu et al, 2001).

### **Biological Control**

The use of biological control organisms is intended to be a permanent change to the environment. Biological control agents are used when weed eradication is not possible. The agent is released to coexist with the weed while bringing the weed population down to acceptable levels. Biologists have long recognized the risks of introducing exotic organisms to control undesirable exotic plants. The first introductions on the mainland of the United States were in 1944 (Coulson, 2000). Safety concerns of early introductions centered on possible risks to agricultural or ornamental plants. Host range tests were conducted to ensure the potential impacts of an introduction were understood prior to release and that no secondary arthropods or pathogens were released in conjunction with the targeted ones. Current host range testing includes testing here and in the agent's country of origin, choice and no-choice oviposition and feeding tests, lab and field tests, and tests varying environmental conditions and plant quality (Littlefield and Buckingham, 2004).

Since the first introduction of a biological control agent, most have been regulated by the Plant Pest Act of 1912, Federal Plant Pest Act of 1957 and the Federal Noxious Weed Act of 1974. The Plant Protection Act of 2000 refined much of the previous legislation to directly address biological control organisms and recognize that some plant pests have positive effects. All legislation puts the regulation of plant pest introductions and interstate movement under the authority of USDA APHIS Plant Protection and Quarantine. In addition, the Environmental Protection Agency regulates pathogens as biological pesticides under the Federal Insecticide, Fungicide and Rodenticide Act of 1972.

USDA-APHIS-PPQ must approve each step in the importation and release of new biological control agents into the United States. Permits for entry into the U.S. must be obtained prior to importation. New agents are imported into approved containment facilities after USDA inspection. After further testing, applications for release are submitted to the Technical Advisory Group (TAG). The TAG reviewers examine the information on taxonomy of target plant and agent, the test plants used, host range tests, and impact to nontarget plants. TAG then makes a recommendation to APHIS for or against immediate release. If TAG recommends release, the researcher must submit an application to APHIS requesting a permit to release the agent into the environment. In accordance with the National Environmental Policy Act and the Endangered Species Act, the application to APHIS must be accompanied by an Environmental Assessment and Biological Evaluation. APHIS is responsible for ensuring the introduction of new biological control agents into the United States is in compliance with NEPA and ESA (Horner, 2004).

The use of pathogens for weed biological control is regulated somewhat differently from arthropods. Exotic pathogens must be screened and tested just as arthropods are. If the pathogen, endemic or exotic, will be applied to more than 10 acres (cumulative in the United States), or if it is formulated for commercial use, it is subject to EPA regulation (USDA, 2003).

Regulation and testing for biological control releases has changed as public values have changed. McFadyen (1998) conducted a review of those working with biological control of weeds and came up with a list of 5 species introduced into the United States that are now known to damage natives. All of these species were originally introduced from 1946-1969 and the effects on nontarget plants were anticipated for these insects from host range testing conducted at the time. Pemberton (2000), in a similar review, established

that of 117 biological control organisms established in the United States and the Caribbean, only 1 uses a native plant unrelated to the target weed. This is an insect introduced to Hawaii in 1902 without host specificity testing. This insect is now suspected of being more of a generalist than originally thought. All of the agents now known to impact nontarget plants were approved for release when native plants were not generally valued as they are today. These releases would not be allowed under current protocols.

### ***Site Restoration/Revegetation***

Site restoration or revegetation is part of any long term strategy to reduce invasive plants. Determining the need for active restoration/revegetation versus passive restoration (allowing plants on site to fill in a treated area) is the first choice when addressing this need. Passive restoration may be appropriate where treated sites leave only small gaps of bare ground and native vegetation on site can provide adequate seed source to fill in such gaps.

Promoting the establishment of desirable plant communities through the manipulation of species composition, plant density, and growth rate is a critical component of invasive plant management (Masters et al., 1996; Masters and Nissen, 1998; Masters and Shelly, 2001; Brooks et al., 2004). Three components of succession could be manipulated; site availability, species availability, and species performance (Cox and Anderson, 2004). Although single control tactics, such as treatment with herbicides, may eliminate or suppress invasive species in the short term, the resulting gaps and bare soil create niches that are conducive to further invasion by the same or other undesirable plant species. On degraded sites where desirable species are absent or in low abundance, revegetation with competitive grasses, forbs, and legumes may be necessary to direct and accelerate plant community recovery, and achieve site-management objectives in a reasonable timeframe.

A two step approach, using a model of ‘assisted succession’ was used to accelerate recovery in sagebrush steppe invaded by cheatgrass. The first step was to convert a site from annual to perennial domination. The second step in the process was to insert native species into the stable perennial matrix using such seedbed techniques as tilling or treatment with herbicide (Cox and Anderson, 2004).

The selection of appropriate species for revegetation is dependent on a number of factors, including management objectives and site characteristics such as soil texture, precipitation/temperature regimes, and shade conditions. Seed availability and cost, ease

of establishment, seed production, and competitive ability are also important considerations and, as a consequence, resource managers in the western United States have historically relied on introduced species that have been selectively bred and marketed for these attributes.

Some success has been found using crested wheatgrass as in the ‘assisted succession’ model discussed above (Cox and Anderson, 2004). Success in establishing native species varied by precipitation patterns and seed bed preparation in plots dominated by crested wheatgrass versus cheatgrass. The study was based in the Great Basin in sagebrush steppe and covered only two years of measurements. While success was shown in amount of native species to germinate and establish when crested wheatgrass was the dominant species, this success was tied to seed bed preparation that created niches for native species development. Crested wheatgrass was not expected to be eliminated with such a strategy, but diversity, structure and function of the resulting community was considered more similar to the original native community. The use of crested wheatgrass may therefore only be appropriate under very specific, controlled situations where native plant community restoration is not a high priority.

Numerous annual or sterile cereal grasses could be used instead of the above persistent non-natives. For example, cereal wheat, barley, annual ryegrass or sterile wheatgrass have been used in restoration efforts. In the case of wildfire recovery (Burned Area Emergency Rehabilitation (BAER) programs, some studies are being done to assess the success of seeding with these species.

In order to conserve and enhance the biodiversity and sustainability of wildland ecosystems, numerous authorities and policies are in place to promote the use of native species in restoration and revegetation. There is debate among restoration practitioners on how close in distance and genetics a seed source should be to the restoration site (Kaye, 2001). The definition of what is ‘local’ varies and should be defined through specific project objectives. Genetically similar seed may have an advantage because it is from locally adapted plants, but could be more costly than using seed from a broader genetic pool such as a watershed or even an ecoregion that can be used for many projects.

The successful use and incorporation of native species, in revegetation of impacted sites will require extensive ecological and biological knowledge and expertise in order to meet both short-term objectives of attaining adequate amounts and levels of competitive plant cover, and long-term objectives of physical and biological site recovery. Although agency knowledge and experience base is growing, education and training is still needed.

There is also a critical need for research efforts that more broadly explore the array and combinations of native grasses and forbs that may be useful in restoration/revegetation. The effects of the timing, as well as the rate and methods of seeding on sites previously infested with invasive plants, have also not been fully examined for most species.

## **Environmental Consequences**

### ***Effects to Native Plants***

#### **Manual, Mechanical**

The removal of invasive plants using manual or mechanical techniques could directly affect native plants and plant communities. Direct negative effects would be unintentional removal or trampling of flowers, fruits, or root systems of native plants, but should be minimal with properly trained crews. Vigor could be reduced in individuals due to damage. The removal of individuals could also directly affect remaining native plant community components negatively by reducing native seed production (if methods such as mowing are used), creating soil disturbance, and opening the canopy (understory, shrub layer or overstory depending on the species). Hand-pulling trials conducted on spotted knapweed in western Montana and on diffuse knapweed in west-central Colorado were 35 percent and 0 percent effective, respectively. The treatments were completed twice per year for two consecutive years, were found to significantly increase bare ground, and were expensive (Duncan et al., 2001). Test plots established on Blue Mountain (Lolo National Forest) and the Lee Metcalf National Wildlife Refuge near Stevensville, Montana, measured effects of hand-pulling on spotted knapweed. Spotted knapweed covered 76 percent and 53 percent of the two sites, respectively. Hand-pulling provided 100 percent flower control and 56 percent plant control at Blue Mountain, but resulted in an increase in bare ground from 2.7 percent to 13.7 percent during the first year after treatment (Brown et al., 2001).

Indirect effects from these changes include microsite shifts such as reduction in productivity, reduction in soil moisture, disruption of mycorrhizal connections and increase in surface temperatures. All of these indirect effects could lead to a shift in species composition further away from a native community. One possible scenario is that the removal of one invasive species would only encourage another invasive to take its place. This could occur through various means of introduction (windblown seeds, human transport etc.).

Communities would be affected positively by providing the space for increased growth in community size. One possible scenario is that removal of invasives will encourage native seed dormant in the soil to germinate due to less competitive conditions. Dremann and Shaw (2002) documented the success of converting live oak woodland from 99 percent exotic species cover to 85 percent native plant cover through a strategy of timed manual/mechanical removal that released the native seed bank. No reseeding was necessary.

### **Cultural**

Grazing affects native plants much the same way as manual or mechanical methods. Individual plants can be eaten, uprooted, or trampled leaving bare space for re-invasion. While grazing to manage weeds on roadsides, trailheads, and larger infestations on the forest may be limited because of the difficulty of maintaining and managing the animals, grazing has also been proven to be a useful tool for invasive plant control. For example, goats and sheep have been used in various areas for controlling knapweed and leafy spurge. Controlled, repeated grazing of spotted knapweed by sheep has been found to reduce the number of 1 and 2-year old spotted knapweed plants within an infestation (Olson et al., 1997). Appropriate grazing by animals preferring invasive species can shift the plant community toward more desired grasses (Lacey et al., 1989). When not properly controlled, however, grazing or other actions of grazing animals (wallowing, pawing up soil) can cause significant damage to a system, and promote the spread and survival of invasive weeds. Overgrazing can reduce native plant cover, disturb soils, weaken native communities, and allow exotic weeds to invade. In addition, animals that are moved from pasture to pasture can spread invasive plant seeds (Tu et al, 2001).

Invasive plants can compensate quickly after the grazing pressure is removed because their seeds are long-lived in the soil, and because they can rapidly increase flower stem production once grazing pressure is removed (Olson et al., 1997 cited in Sheley et al., 1999).

### **Prescribed Fire**

Use of prescribed fire will affect native plant communities in a similar manner to mechanical and manual treatments, but will also change soil chemistry and composition. The litter and duff layer including thatch would be reduced, allowing natives a better opportunity for seed germination. Likewise, invasive seeds may germinate and some invasive plants will aggressively sprout after fire. High temperatures or smoldering conditions could kill seeds of not only invasive plants, but also natives; and could

damage important mycorrhizal connections. Therefore, the timing of prescribed burns is important to consider. This timing may interfere with important growth periods for native species.

Fire may encourage invasive plants even in communities that have evolved with fire. This could happen because plant communities evolve not in association with fire per se, but with a particular fire regime. If the fire regime has been altered, vulnerability to exotic plant invasion increases (Keeley, 2001). Given these confounding factors, a combination of treatments (such as fire and herbicide or fire and manual) would be most successful.

### **Biological**

Even though control agents are reviewed and approved by APHIS prior to release in this country, there is a slight risk that an approved agent the Forest Service releases may unintentionally affect native plants or animals. There also remains the possibility that regardless of what the Forest Service does, unapproved agents or agents known to affect non-targets will spread from neighboring lands to National Forest lands.

There are very few post-release studies on the effects of biocontrol introductions on nontarget plants or animals (D. Simberloff and P. Stiling 1996, Howarth 2001). Perhaps the most relevant studies of direct non-target effects concern the thistle seedhead weevil, *Rhinocyllus conicus*, introduced into North America for the control of Eurasian thistles in the genus *Carduus*, primarily musk thistle, *C. nutans* (Zwolfer and Harris 1984, Turner et al., 1987, Louda et al. 1997). The original releases were made in Canada in 1968 and releases in both the U.S. and Canada continue today. Approval for the release of this insect was granted knowing that the weevil's host range included three native North American thistle genera. At that time, there was little concern for possible negative impacts on native thistles. In addition, female egg-laying behavior was expected to restrict the weevil's host range. Current evidence shows this weevil continues to expand its geographic and host range, which now includes a close relative of the federally listed threatened Pitcher's thistle (*Cirsium pitcheri*) (Louda et al. 1997). Recent research rebuts the idea that the host-specificity of this weevil has changed since the original testing 30 years ago (Arnett and Louda, 2002).

*Rhinocyllus conicus* would not be approved for release by the current standards used by USDA APHIS. Agents known to affect non-targets with a likelihood of encountering those non-targets if introduced are no longer approved for release (USDA, 2003). APHIS

modified the testing process in the mid-1980's to include more potential hosts in host specificity testing. APHIS continues to work on refining regulations and procedures for introducing biological control agents (Andres et al., 2000).

While little studied, there are a few examples of indirect effects on nontargets resulting from biological control introductions. Callaway, DeLuca and Belliveau (1999) found the reproductive output of native *Festuca idahoensis* planted with spotted knapweed (*Centaurea maculosa*) was lower when the introduced root moth, *Agapeta zoegana*, had attacked neighboring knapweed. A study of native deer mouse (*Peromyscus maniculatus*) diets found introduced knapweed gall flies were the primary food item for most of the year and over 80 percent of the winter diet (Pearson et al., 2000). These studies illustrate ways agents can indirectly affect their new communities and also ways their communities may change agent effectiveness. Increased emphasis on prerelease ecological testing may reduce these indirect effects. The International Code of Best Practices for biological control of weeds provides further guidelines for practitioners involved in redistribution that, when followed, will reduce these indirect effects.

### **Site Restoration/Revegetation**

While planting or seeding will provide the positive effect of covering bare ground to reduce the chances of re-invasion and enhance a native plant community, species composition could be negatively affected by inappropriate choices during revegetation or restoration. First, the choice to revegetate when not necessary may occur; secondly, a material that may be inappropriate for specific site conditions could be chosen. With sterile wheatgrass, Keeley (2003) found that seeding with cereal wheat, at high seeding rates, reduced invasive species after two years. The study also found decreases in species richness and ponderosa pine seedlings. The dense stands of wheat did appear to reduce erosion, but left thick thatch which increased fire hazard at least initially. Such studies suggest determining if seeding is necessary and the amount of seed per acre considered crucial for reducing disruption to ecosystem processes.

Although some introduced species will continue to be used in site restoration, the extensive past use of highly competitive and persistent non-natives (e.g., smooth brome, orchardgrass, timothy, and crested wheatgrass) has had adverse impacts on the diversity and health of our native forest, rangeland, and aquatic ecosystems (Romo, 2005; Bartos and Campbell, 1998; Brown, 1995; Covington and Moore, 1994; Cetwyler, 1971; Kaufmann et al., 1994; Kay, 1994; Lesica and DeLuca, 1996; Mills et al., 1994).

The use of crested wheatgrass in assisted succession experiments is showing some success under specific conditions (Cox and Anderson, 2004). On the other side of the argument, crested wheatgrass is considered invasive in the native prairies of Saskatchewan where experiments to determine its invasiveness and guidance for controlling the species have been published (Romo, 2005; Saskatchewan Watershed Authority Fact Sheet, no date). Studies linking invasiveness of the species with environmental factors are pending publication (Henderson and Naeth, 2004; Hansen and Wilson, 2004).

### ***Effects to Wildlife***

Wildlife species may be adversely affected by invasive plant treatment methods. All treatment methods have the potential to disturb, temporarily displace, or directly harm various wildlife species. Successful control of invasive plant infestations provides long-term benefits by restoring native habitat. Treatment of larger infestations may create more disturbances for longer periods than small infestations, but the specific amount and duration is largely dependant upon specific treatment method. Several techniques can create bare ground, which may reduce cover and expose certain species to increased predation. Large tracts of bare ground can alter migration and dispersal of some species (Semlitsch, 2000). The likelihood of these effects depends on the size and distribution of bare ground created.

The effects of the invasive plant treatment are also relative to the size and locations of existing and future invasive plant infestations. Treatments of infestations along disturbed roadsides are not likely to substantially affect terrestrial wildlife populations, since this vegetation type does not provide essential habitat for native wildlife species, and it consists of long, narrow areas spread over large distances. Adverse effects to individuals using the roadside vegetation at the time of treatment could occur.

Treatments of moderate infestations may pose the greatest risk to native wildlife. In moderately infested areas, enough native habitats may remain to support some native wildlife, and the infestation may be large enough to require more intensive and extensive treatment techniques. Very large infestations and monocultures of invasive plants do not support native wildlife populations and the presence of native wildlife in these areas is greatly reduced in comparison to native habitat (see Duncan and Clark, 2005).

### **Manual**

Manual treatments can result in trampling of non-target plants and animals and create bare ground. The degree of threat and effect from manual treatments depends on the number of workers present and the size of the area being treated. Because manual techniques are slower than mechanical or chemical methods, the duration of disturbance, caused by the presence of people, may be longer in the treatment area. The slower pace of work allows animals in the area to leave and reduces the risk of direct harm from trampling. Bare ground is likely to be patchy in distribution with this method and less likely to interfere with animal movement or dispersal.

### **Mechanical**

Some mechanical treatments may crush small mammals, reptiles, amphibians, or eggs of ground-nesting birds. Hand-held mechanical equipment, like chainsaws and string trimmers, can be used very selectively on target plants and may be less likely than larger equipment to directly harm wildlife. Use of vehicle-mounted mechanical equipment (mowers, tractors with disks or hammer flails, bull dozers with brush rakes, etc.) is much less selective and more likely to directly harm small wildlife species. Vehicle-mounted equipment is most often applied to monocultures of invasive plants on gentle slopes or road verges, and even though those areas do not provide preferred or suitable habitat for most native wildlife, adverse effects from disturbance or crushing are still possible. Mechanical treatments may produce more bare ground, reducing cover, exposing more soil to erosion, potentially disrupting dispersal or foraging patterns of small animals, and possibly exposing some to increased predation as a result of decreased cover. Mechanical methods generate more noise than other treatments, except for aerial applications, and have a higher likelihood of disturbing species that are secretive or sensitive to noise.

### **Cultural**

Livestock grazing conducted to reduce invasive plant populations while increasing native plant populations, would provide long-term beneficial effects to wildlife. Grazing would also cause short-term disturbance similar to mechanical methods, resulting in more bare ground and decreased cover for wildlife. Fertilization may increase competitive advantages of native plants and improve forage quality and quantity, contributing to improved wildlife habitat. However, in naturally nutrient-poor soils, fertilization may give the competitive advantage to invasive species (Brooks, 1999), which would further degrade wildlife habitat. Off-site movement of fertilizer can have substantial adverse effects to aquatic wildlife habitat and may have toxic effects to some species as well.

**Prescribed Fire**

Prescribed burning may cause mortality to animals lacking the ability to escape and would reduce cover and food provided by intermixed native plants. Fires can produce a large amount of bare ground that may fragment habitat or expose small animals to increased predation. Smoke from prescribed fires could temporarily disturb nesting birds and other wildlife long distances down wind from the project area.

**Biological**

Biological control methods will not directly affect native wildlife species; however, recent studies have found that native rodents may take advantage of the food source provided by biological control agents (Pearson et al., 2000). Biological control methods that reduce invasive plant populations, increase native plant populations, and provide a supplemental food source are indirectly beneficial to wildlife. Any biological control agents that affected native plant species could adversely affect wildlife.

**Site Restoration/Revegetation**

Reseeding or revegetation to increase competition with invasive plants can cause short-term disturbance to wildlife similar to manual or mechanical treatments, depending on specific methods used. If native or non-native, non-invasive forage species are used in restoration or competitive plantings, increased food and native habitat could benefit wildlife. Restoration activities have the potential to restore important wildlife habitat faster than natural or passive revegetation.

***Effects to Soil***

The intensity and extent of non-herbicide treatment effects to soil productivity will vary, depending on treatment type and extent of area treated; soil characteristics such as texture, moisture, and depth of the organic layer; as well as climate and hydrologic, chemical, and biological properties. Vegetation prevents soil erosion and subsequent loss of soil productivity.

**Manual and Mechanical**

Manual and mechanical treatments that disturb soil, such as grubbing and pulling, when carried out over a large area, may cause a significant local soil disturbance. Manual and mechanical treatments are expected to cover relatively small areas, with effects to soil productivity localized to the treatment area, though some soil may be moved off-site through wind or water erosion.

Wheeled or tracked machinery can compact soil. Soil compaction eliminates soil pores and so reduces water infiltration, plant growth, and increases the potential for runoff, and erosion. One pass of heavy equipment over wet soil can cause enough compaction to reduce tree growth, and the effects of this compaction can last for decades (Perry, 1994). Best management practices minimize effects of wheeled or tracked machinery to soil productivity due to compaction.

### **Cultural**

Potential impacts of grazing on soils include increased bare ground, increased erosion, decreased litter layer, increased compaction, decreased infiltration, and decreased fertility. Careful management of the grazing animals can significantly reduce the effects of grazing on soil productivity.

### **Prescribed Fire**

The risk of harm to soil productivity from prescribed fire is low to high, depending on soil and climate conditions during burning and fire intensity. Prescribed burning has the potential to bare large areas of soil, and thus increase surface erosion. High intensity fire may cause the formation of a hydrophobic surface layer on the soil. A hydrophobic surface layer repels water and increases erosion by increasing the volume of surface flow during rain events. High intensity fires are not generally used to treat invasive plants.

Depending on fire intensity, significant amounts of the nitrogen, phosphorus and potassium content of vegetation burned in a fire is volatilized (Perry, 1994), and is no longer available to take part in soil nutrient cycling processes. After a fire, decomposing roots of dead plants and the mineral content of ash add a significant nutrient pulse to the soil. If some vegetation and soil microbes remain, these nutrients can be captured for cycling in the new plant community. If the soil biotic community is heavily impacted by high intensity fire, the nutrient cycling ability of the soil may be reduced and nutrients may be lost to surface or ground water.

Stendell, et al. (1990) studied the mycorrhizal community in a ponderosa pine forest in the Sierra Nevada Mountains before and after a low intensity fire. They found an eight-fold reduction in mycorrhizal biomass in the litter and organic layers, but no reduction in mycorrhizal biomass in mineral layers. Grogan, et al. (2000) studied the effect of a severe fire on mycorrhizal community in a bishop pine forest in northern California. They found that after 1½ years, all regenerating pine seedlings were associated with at least one mycorrhizal fungus, although the mycorrhizal fungi present in the burned forest

differed from those present in neighboring unburned forest. Another study, in Scots pine stands in a Swedish boreal forest found that low intensity wildfires had little effect in the mycorrhizal fungal community (Jonsson, et al., 1999). In general, research indicates that a functional mycorrhizal fungi community is present in the soil after fire, even severe fire. Freidman's study (1989) on soils that had shifted from fungal dominance to bacterial dominance suggests that if natural regeneration of the plant community does not take place on the burned area, native vegetation should be planted quickly to provide suitable hosts for the mycorrhizal fungi.

Prescribed fire as a treatment for invasive plants is expected to be a very small portion of the prescribed fire program in Region Six. Implementing prescribed fire as outlined in the National Fire plan should minimize negative effects to soil productivity.

### **Biological**

Most biological treatment agent complete their life cycles above ground, and these organisms are not likely to directly affect soil productivity. Biological treatment organisms that spend at least a portion of their lives below ground may affect soil processes. The root moth *Agpeta zogana*, introduced as a biological control of spotted knapweed (*Centaurea maculosa*), appeared to cause a reduction in the reproductive output of the native *Festuca idahoensis* planted with the spotted knapweed, indicating a reduction in soil productivity (Callaway et al., 1999).

### **Site Restoration/Revegetation**

The risk of harm to soil productivity from planting or seeding is unlikely to low. Planting or seeding native or non-invasive species is likely to occur over small areas. Manual methods are generally used for planting and seeding, though hand carried power tools are sometimes used. Planting and seeding will protect soil from surface erosion.

The risk of harm to soil productivity from fertilization, done in conjunction with seeding or planting, is low to moderate. Fertilization can change soil properties and these changes may not be easily reversed. For instance, fertilization and watering of a shortgrass steppe ecosystem led to invasion by the non-native *Kochia coparia* (Vinton and Burke, 1995). *Kochia coparia* continued to dominate 20 years after fertilization and watering stopped. Fertilization projects are likely to be small and affect small areas, so effects are likely to be minor and localized. Best management practices minimize negative effects.

The risk of harm soil productivity from mulching is unlikely to low. Mulch application is likely to be manual and affect small areas. Mulching prevents soil erosion, protecting soil productivity. Decay of the mulch could temporarily affect nutrient cycling.

### ***Effects to Fish and Aquatic Invertebrates***

The intensity and extent of treatment effects to fish, aquatic invertebrates, and their habitat will vary, depending on amount of area treated; soil type, proximity of the treatment to water, hydrologic regime and weather conditions during and after treatment; temperature, channel morphology and large woody debris; and biota present in surface water.

Riparian vegetation is important to preventing or slowing introduction of sediment, particularly fine sediment, to streams. Loss of vegetation in riparian areas during treatment may temporarily increase fine sediment, turbidity, or sedimentation in a stream. Stream shade provided by riparian vegetation prevents increased water temperature due to solar radiation. Where invasive plants prevent the growth of trees or other native vegetative cover, invasive plant treatment may restore shade in the long term. Alternately, treatment could result in temporary loss of shade and increased stream temperatures.

### **Manual and Mechanical**

Manual and mechanical treatment effects to riparian function, water quality, and aquatic biota depend on soil properties, climate, distance to surface water, and the extent of the mechanical treatment. Manual and mechanical treatments are expected to cover relatively small areas within watersheds. Manual and mechanical treatments within riparian areas that disturb soil, such as grubbing and pulling, carried out over a large area, may lead to increased erosion and stream sedimentation. Sedimentation may adversely affect fish by covering eggs or spawning gravels, reducing prey availability, or directly harming fish gills. In lower intensity non-native plant infestations, non-target vegetation left on the treatment site can reduce the potential for erosion and subsequent sediment delivery to streams or other water bodies.

The risk of harm to aquatic ecosystems due to fine sediment production from manual treatment or use of motorized hand tools is low, and short-term, resulting in effects likely to be localized and minor. Best management practices at the site-specific scale are likely to prevent long-term negative effects. Depending on the scale of treatment, large riparian

areas treated with motorized hand tools may moderately increase the risk to aquatic environments.

The risk of harm to aquatic environments from use of wheeled or tracked machinery will vary, depending on the extent of treatment area and proximity to aquatic environments. Soil compaction within riparian areas can prevent the establishment of native vegetative cover. Best management practices at the site-specific scale will minimize effects of wheeled or tracked machinery to riparian and aquatic ecosystems due to soil compaction.

### **Cultural**

The use of livestock, primarily sheep or goats, to control invasive plants, is a relatively new treatment that has gained attention recently (Olson et al., 1997). The treatment of invasive plants by grazing animals requires a highly specialized operation, often involving animals that are “trained” to forage on the target plant, and usually involving temporary fencing to keep the animals within the target area (Peters, personal communication, 2004). The livestock species, grazing intensity, and management of the grazing animals used to treat invasive plants are different from grazing for other purposes. Also, the specific use of livestock in this type of control effort has not been utilized extensively in riparian areas or near aquatic ecosystems. Careful management of livestock used as a treatment tool can significantly reduce the effects on riparian areas and aquatic environments.

Fertilizer is used to promote native plant species at the expense of invasive plant species, but has been done infrequently in the region, and is not likely to have large-scale effects. Fertilizer use near streams could produce localized adverse effects if the fertilizer was introduced into the water via runoff. Seeding is not likely to have adverse effects to aquatic ecosystems.

### **Prescribed Fire**

The risk of harm to riparian function, water quality, or aquatic species from prescribed fire depends on fire intensity, timing, and land form, among other factors. Prescribed burning has the potential to bare large areas of soil, and thus increase both surface erosion and sedimentation of streams. High intensity fire may cause the formation of a hydrophobic surface layer on the soil. A hydrophobic surface layer repels water and increases erosion by increasing the volume of surface flow during rain events.

Groundwater recharge may be reduced in areas with hydrophobic soils.

Heavy runoff from burned areas can increase water pH, indirectly affecting aquatic biota. Effects to watersheds are dependent on the extent and intensity of the fire. Prescribed fire as a treatment for invasive plants has been rarely used, and is expected to be a very small portion of the invasive plant program in Region Six. Implementing prescribed fire as outlined in the National Fire plan consultation with regulatory agencies should minimize effects to the aquatic environment (Northwest National Fire Plan Consultation Process, [www.or.blm/fcp/documents/salmonids](http://www.or.blm/fcp/documents/salmonids)).

### **Biological**

Biological controls, targeted to a single species of invasive plant, are unlikely to result in adverse effects to riparian function, water quality, or aquatic species. Biological controls act very slowly, often taking a decade or more to substantially reduce the invasive plant population. Therefore, indirect effects to water quality and aquatic species are unlikely.

### **Site Restoration/Revegetation**

Negative effects to fish and aquatic ecosystems from planting or seeding are unlikely. Planting or seeding native or non-invasive plant species is likely to occur over small areas. Manual methods are generally used for planting and seeding, though hand carried power tools are sometimes used. Planting and seeding in riparian areas will speed establishment of vegetative ground cover, preventing fine sediment introduction to streams.

Fertilization done in conjunction with seeding or planting, may result in minor and localized effects. Depending on fertilizer type, application method, soil type, weather during and after application, and proximity to surface water, nutrients can be delivered to streams. High nutrient loads in water bodies can lead to algal blooms, increased biological demand, water chemistry effects, and changes in biota. Ammonia, a common ingredient in fertilizers, is listed in both Oregon and Washington with specific water quality criteria for 303(d) lists. Fertilization projects are likely to be small and affect small areas within watersheds. Best management practices at the site-specific scale will minimize effects from fertilizer use in riparian areas.

Mulch application is likely to be manual and any risk of harm riparian function, water quality, or aquatic species from mulching is unlikely. A significant amount of mulch, or decayed mulch, would have to enter a water body in order to impact the aquatic ecosystem; a scenario that is unlikely to occur. The use of mulch for restoring sites

previously infested with invasive plants is unlikely to negatively affect riparian areas or aquatic ecosystems.

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