Invasion by exotic species is one of the most significant ecological threats of our modern era rivaling even highly warned and researched concerns such as ozone depletion, global warming, and loss of biodiversity (Shea and Chesson 2002, Vitousek et al. 1996). An invasive plant on rangelands is an alien plant spreading naturally (without direct human assistance), to significantly alter composition, structure or ecosystem processes. Weed invasion into rangeland communities often results in reduced biodiversity, increased soil erosion, degradation of wildlife habitat, and reduced carrying capacity for livestock (Sheley and Jacobs 1997, DiTomaso 2000). This weed-induced degradation of rangeland ecosystems is an important concern because rangelands constitute a major portion of western North America and are used for livestock production, wildlife habitat, and recreation.

The challenges of controlling invasive plants on rangelands include vast roadless areas that limit access for weed control and lands of low economic value making chemical and mechanical control impractical. These challenges favor the use of biological and cultural control. Insects and microbes for biocontrol can be quite effective but are difficult, expensive, and time consuming to develop. However, there is a readily available and under-exploited agent that is fast proving very effective for weed control. Along with fire, grazing of domestic livestock may be the earliest vegetation management tool employed by humans. We suggest that the challenges of rangeland weed management may be addressed with the careful sharpening of this old tool. Past success with sheep and goats to control several rangeland weeds, such as leafy spurge (Euphorbia esula), has fueled interest in grazing for weed control (Olson and Lacey 1994, Walker et al. 1994). Furthermore, livestock grazing has one distinct advantage over other control methods; in the process of controlling a noxious plant, grazing animals convert the weed into a saleable product.

Prescription grazing is the application of livestock grazing at a specified season, duration and intensity to accomplish specific vegetation management goals. Controlled grazing of this type is being employed throughout North America on public and private land and is proving to be a promising tool in the battle against weeds. Awareness of invasive exotic weeds has raised concern over the potential role of livestock in spreading these weeds and served to fuel interests to get livestock off of public range land, which has succeeded in several areas. However, other areas are welcoming livestock in an effort to heal the very lands they were held partially responsible for destroying.

How Livestock Can Control Weeds

Given the correlation between livestock grazing and alien plant invasion, why are managers now looking to livestock to control invasive plants? Just as venom can be converted into anti-venom to treat the very symptoms it caused, if managed correctly, grazing animals can provide more effective, sustainable weed control than herbicides alone and improve pasture quality with less effect on non-target species.

Just as the selective grazing of livestock can result in weed dominated communities, with careful management, selective grazing can be used to alter the community composition in favor of native species. Competition is a two-way street, and healthy perennial bunchgrasses can successfully compete with invaders and inhibit their spread. Grazing animals can influence weeds directly by eating or damaging the plants, or indirectly by "conditioning" the pasture and making the desirable vegetation more competitive and better able to resist subsequent weed invasion. The goal of using livestock to control weeds is to manipulate patterns of defoliation to place a target plant at a competitive disadvantage relative to other plants in the community. Walker and colleagues (1994) suggests that there are two approaches to placing an invasive plant at a competitive disadvantage in the community: 1) use grazing management that harms the target weed by grazing at the time, frequency when the weed is most vulnerable, and 2) modify the grazing behavior of animals to cause them to concentrate their grazing efforts on the target weed instead of the desirable forage. These two approaches form the basic framework of prescription grazing.

How Livestock Contribute to Weed Invasion

Livestock grazing, like any tool, can be misapplied and cause harm instead of repair. Overgrazing has often been implicated in encouraging the spread of noxious weeds. However, grazing could be honed into a highly effective weed management tool with precise application based on an understanding of plant-herbivore interactions.

Poor grazing management practices have contributed to the introduction and spread of invasive plants by the degradation and reduced competitive ability of the native plants. For example, the native perennial grasses of the North American
Intermountain West have low seedling vigor and do not recover rapidly after grazing. Decades of overgrazing during the open range era paved the way for opportunistic winter annual grasses, like cheatgrass (*Bromus tectorum*). These grasses are fierce competitors that have high seedling vigor and are able to germinate, establish, and complete their life cycle before the summer dry period. The exploitation of resources by the annual grasses combined with the overgrazing resulted in a decline in perennial grass populations. A shift in grazing management to better utilize the annual grasses then left the community open to the next wave of invaders, the forbs.

To continue the invasion process, alien propagules must be dispersed into new areas and deposited on sites conducive for germination and establishment. “Safe sites” may be areas away from conspecific adults, seedling predators, or may simply be a site with greater resource availability. Livestock contribute to the creation of safe sites through their mechanical impact on rangelands. Continued grazing increases bare soil, reduces plant litter, concentrates nutrients on certain areas, and breaks up biological soil crusts (Callihan and Evans 1991). Grazing activity over an extended period of time can also adversely affect bulk density, soil moisture content, soil organic matter, and increase soil susceptibility to wind and water erosion (Dormaar and Willsm 1998). This increase in erosion can result in burial of weed seeds, thereby, increasing germination rates.

Livestock can disperse seeds by serving as transportation vectors for seeds that adhere to their coats (fur, wool, or hair). Several weed species including; houndstongue (*Cynoglossum officinale*), the knapweeds (*Centaurea* spp.), and cheatgrass practice this form of dispersion. Livestock can also spread seeds by consuming and passing viable seeds through their digestive tract. While the total number of viable seeds that survive the digestive tract is reduced, those seeds that do survive are deposited in a protective pile of concentrated nutrients that can increase the chance of germination. Sheley and colleagues (1998) found that up to 22% of spotted knapweed seeds can remain viable after passing through the digestive tracts of sheep and mule deer. In another study by Lacy and colleagues in 1992, 40% of leafy spurge seeds ingested by sheep and 60% of those ingested by goats were viable on the initial day of passage. All seeds were passed within 9 days of consumption and viability of all seeds was 0% by the 5th day after ingestion. The longer the rate of passage through the digestive system the fewer viable seeds were recovered.

It is also widely believed that, because of open niches in the plant community structure, certain areas were predisposed to invasion by alien plants. Research on western Montana found that diffuse knapweed rapidly invaded a bluebunch wheatgrass (*Agropyron spicatum*) community in the absence of grazing (Lacey et al. 1990). Similarly, research on spotted knapweed determined that defoliation of grasses is not required for this weed to become established and that moderate defoliation did not accelerate the invasion process (Sheley and Jacobson 1997). Both spotted knapweed and leafy spurge have been documented in Glacier National Park and leafy spurge has invaded the remote Danaher Creek area of the Bob Marshall Wilderness, where there is no livestock grazing. Similarly, Anaho Island in Pyramid Lake, Nevada has not experienced livestock grazing for over 100 years and is dominated by cheatgrass and red brome (*Bromus rubens*). Svejcar and Tausch (1991) contend that these annual grasses are sufficiently dominant on the island that the chances of natural succession progressing to pristine vegetation appear minimal.

**Steps in Developing a Grazing Prescription**

Just as a medical doctor requires extensive training to determine the illness or prescribe the right treatment, formulating a grazing prescription requires extensive knowledge of plant ecology, animal behavior, and plant-animal interactions. Based on these three components, a grazing prescription should include specific information on the season and intensity of defoliation, the species and even breed, sex, or age class of animal to use, and the stocking rate that will result in the most harm to the target plant and still maintain healthy rangeland ecosystems. A successful grazing prescription should: 1) cause significant damage to the target plant (Walker et al. 1992); 2) limit irreparable damage to the surrounding vegetation (Walker et al. 1992, Olson and Lacey 1994); 3) be consistent with livestock production goals (Olson and Lacey 1994, Mosley 1996); and, 4) be integrated with other control methods as part of an overall weed management strategy (Sheley et al. 1996a).

**Selecting the Right Species**

The species of livestock best suited for weed control depends on the plant species of concern and the production setting. Cattle have large rumens that are well adapted to ferment fibrous material and are classified as grass and roughage eaters. They are therefore generally superior to goats or sheep to manage fibrous and abundant herbaceous vegetation such as dormant grasses. Goats have narrow and strong mouths well designed for stripping individual leaves from woody stems and chewing branches. They are classified as browsers and are used extensively in the southwestern United States for management of invasive woody plants on rangelands such as juniper and mesquite (Brock 1988, Hanselka and Paschal 1992). Goats also have a large relative liver mass compared to cattle or sheep and may therefore more efficiently process plants that contain secondary compounds such as tannins or terpenes.
This could explain why goats are more effective than sheep or cattle for the control of leafy spurge, which contains a host of allelochemicals (Walker et al. 1994).

Sheep are generally considered an excellent species to accomplish weed control (Olson and Lacey 1994). Sheep possess a narrow muzzle and a relatively large rumen, per unit body mass, which allows them to selectively graze and yet tolerate substantial fiber content. These morphophysiological features result in diets generally dominated by forbs. Most of the troublesome weeds that threaten rangelands are forbs. Sheep are also small, sure-footed, and well suited for travel in rough topography which may not be easily accessible for weed control. Furthermore, sheep are gregarious creatures that are generally managed by human herders creating opportunity for careful and strategic application of grazing in specific weed dominated areas. Sheep have been used successfully for the control of several rangeland weeds including leafy spurge, tall larkspur (Delphinium occidentalis), tansy ragwort (Senecio jacobaea), and others (Walker et al. 1994, Olson and Lacey 1994, Popay and Field 1996, and DiTomaso 2000).

Selecting the right species is not the final step in matching the tool to the job. Diet composition varies among breeds and even between individual animals. What an animal consumes depends on their nutrient requirements and their past experience with a food. While animals can be encouraged to select specific plants for food, they will never habitually consume those plants if they do not receive a nutritional benefit from them. However, digestive capabilities and nutrient requirements vary throughout an animal’s life potentially resulting in different nutritional benefits at different times. Therefore, age, body condition, sex, and physiological state could have a profound affect on diet selection and preferences.

**Season and Intensity of Grazing**

Prescription grazing for weed control requires the application of defoliation when the weed is most palatable to livestock and most susceptible to defoliation. For instance, cheatgrass is highly palatable and is effectively reduced by heavy spring grazing (Mosely 1996). Furthermore, grazing programs should be implemented when the associated or desired plant community expresses high tolerance to grazing.

The season and intensity of defoliation strongly effect the ability of plants to regrow following defoliation. Most plants are tolerant of herbivory early in the growing season when adequate nutrients and soil moisture are available for regrowth. However, as the season progresses, nutrient availability is reduced and plants are putting all of their energy into seed production. Consequently, grazing during this time can be very detrimental to the plant (Briske 1991). Furthermore, grazing weeds during seed set may not be advisable due to the risk of livestock spreading weed seeds. Seed dispersal of weeds by animals can be minimized by avoiding livestock grazing in weed-infested areas during flowering and seeding stages. Animals may also be held in pens for a short time period to allow passage of all seeds through the digestive system before moving them to uninfested areas (Lacey et al. 1992).

Perhaps the main factor determining stocking rate is the density of the weed infestation and the palatability of the plant. Sparse infestations of relatively nutritious, palatable plants like spotted knapweed may be best controlled with light stocking rates that can take advantage of an animal’s preference for the plant. More dense infestations or less palatable weeds may require a heavy stocking rate to force a more even utilization of forage. In extremely dense infestations, animals are often “mob-stocked” to facilitate complete removal of all forage. This can be accomplished by herding or fencing animals onto those areas until the desired affect is achieved.

**Integrating Livestock Grazing Into Weed Control Programs**

Finally, it is necessary to consider and suggest ways to incorporate prescription grazing into ecologically-based integrated weed management systems with careful attention to positively directing community change, not just removing a weedy species (Sheley et al. 1996a). Incorporating grazing management into weed management plans has been recognized as one of the key components in successfully addressing weed problems. Research by Lym et al. (1997) on leafy spurge indicates that grazing could increase the efficacy of herbicides and insect biocontrol (L. Rittenhouse, personal communication). Sheep grazing may also be used to reduce recruitment of weeds after herbicide treatment. These studies suggest that grazing holds potential to increase the effectiveness of integrated pest management (IPM) systems while reducing the use of herbicides. The careful application of a prescribed grazing program will undoubtedly improve the ability of livestock to suppress weeds and may strengthen integrated systems that include prescription grazing. Using grazing animals to control noxious plants is a readily available approach because it is already the dominant use of western rangelands. However, making grazing an active part of a weed control program will require greater dedication and commitment to grazing management techniques. Grazing guidelines must be developed for this technology to be utilized for maximum effectiveness.

A fundamental principle of rangeland weed management is the early identification and control of invasive plants. It is likely that grazing programs could be useful in early stages of plant invasion to reduce colonization and slow the rate of invasion. When a
weed reaches moderate densities in the community, suppression of plant performance may be a tangible goal for prescription grazing. Once a community is dominated by a particular weed, realistic grazing goals may shift to using the weed as forage and preventing the proliferation of other exotic plants that may be less palatable or more ecologically damaging.

Costs Associated With Prescription Grazing

Prescription grazing holds great opportunity for incorporation in a successful weed control program, however, controlled grazing is not without cost. Animals must be purchased, maintained in proper health, and closely monitored to minimize harm to desirable forage. This may require keeping an experienced herder with the animals at all times and often necessitates penned the animals at night. Other expenses may include stock dogs, portable fencing, and remodeling of livestock handling facilities. If the vegetation management is to occur in close proximity to towns and cities, then extra care must be taken to protect livestock from domestic dogs, and ensure that they remain either fenced or directly under the herder’s control. When controlling vegetation containing secondary compounds or of very poor nutritional quality it may be necessary to supplement animals.

Finally, the animal production consequences of employing grazing to accomplish weed control must be elucidated. Despite the potential biological efficacy of using sheep to control weeds, sheep will not be widely used for weed control until it is shown to be compatible with production goals (Olson and Lacey 1994, Mosely 1996). For some weeds, such as leafy spurge, sheep used for weed control may outperform their counterparts on non-infested rangelands (Fay 1991). However, employing animals to control weeds of low nutritional value, such as mature fibrous weeds, will undoubtedly result in some production losses.

Some argue that sheep grazing will never be an effective weed management tool because sheep availability is limited. However, sheep enterprises based on weed control are becoming more common throughout the rangelands of western North America (Olson and Lacey 1994). These enterprises are taking weed control with livestock past the experimental phase and actually making their living solely by fulfilling vegetation management contracts with livestock (Daines 2002). Established sheep enterprises may also consider including prescription grazing for weed control as a part of their grazing plan if it is proven to not be substantially detrimental to sheep production. Detailed information is needed on the impacts of weed consumption on sheep production before it will become widespread.

Conclusions

If managed correctly prescription grazing could prove to be a winning situation for all involved. Not only does it provide a service to land owners and managers that may not be achieved in any other way, but it could also provide a new avenue of income to struggling livestock producers. It is essential that we continue to gather and share information so we can constantly sharpen this “new” tool in range management.

Literature Cited


