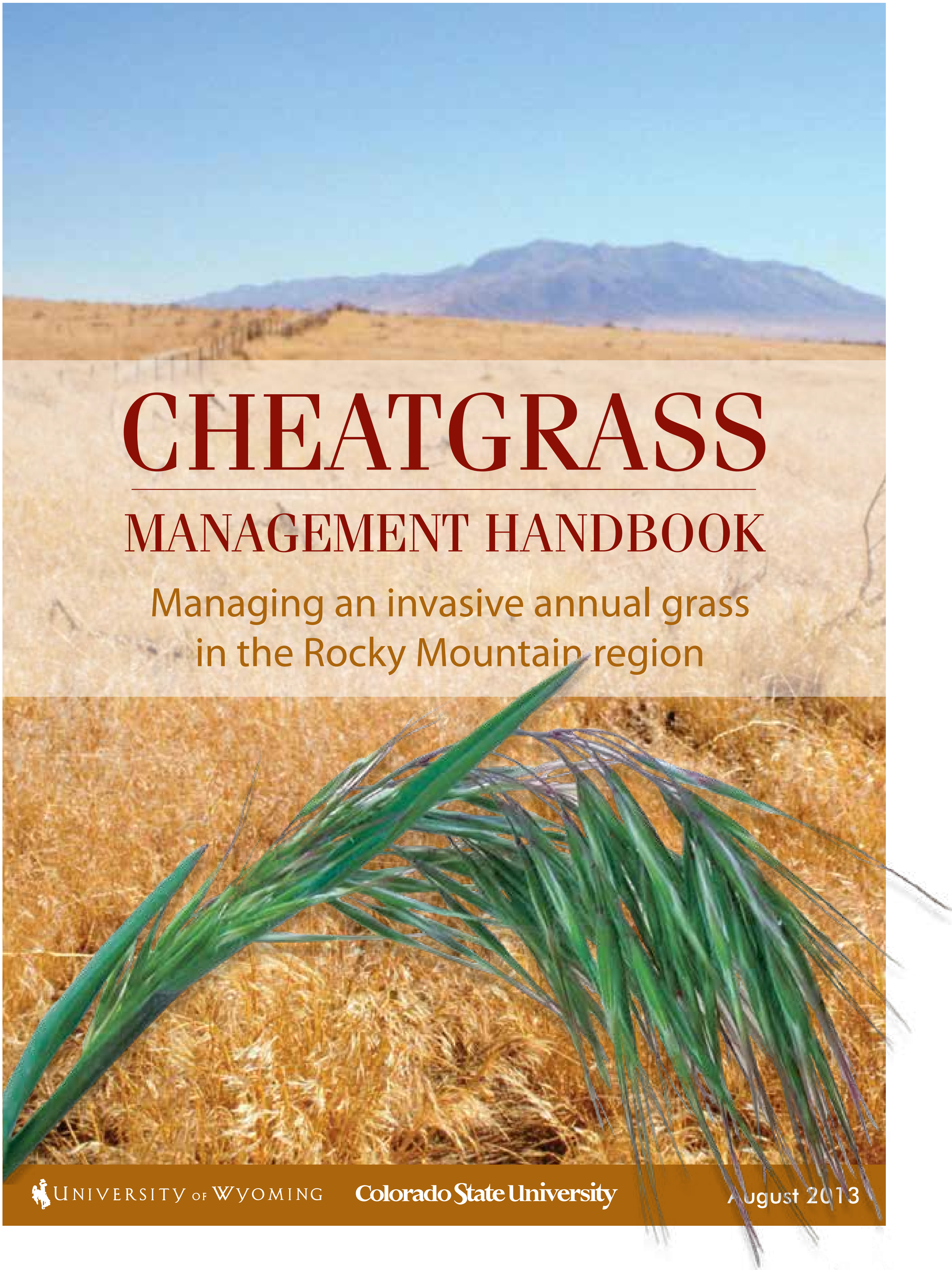

CHEATGRASS

MANAGEMENT HANDBOOK

Managing an invasive annual grass in the Rocky Mountain region

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Contents

Introduction

The annual grass cheatgrass (*Bromus tectorum* L.)—or downy brome—is one of the most significant invasive weeds in the western United States because it reduces forage quantity and quality, alters wildfire regimes, impacts species diversity, and reduces wildlife habitat. In this handbook, we present information that should assist in developing a strategic approach to managing this invasive annual grass. We focus on managing cheatgrass in rangelands and natural areas but not in cultivated croplands. Many of the principles discussed here also apply to other invasive weeds in natural systems, and we encourage readers to incorporate the strategic management framework into other weed management programs. This handbook is not designed to be a comprehensive compilation of all literature related to cheatgrass, but rather a guide to assist land managers and others with developing a cheatgrass management program. The framework described here encourages managing an "ecological system" rather than viewing programs simply from the perspective of killing an undesirable plant.

Weed management decisions depend on the biology of the target weed and how it affects the system it has invaded. Chapter 1 presents an overview of the biology of cheatgrass and its history of introductions and spread and its impacts on natural systems. Chapter 2 discusses human dimensions associated with weed management and how various groups may view cheatgrass differently. The establishment of clear goals and obtainable objectives is also presented in Chapter 2. Chapter 3 covers the importance of collecting vegetation data and is complemented by step-by-step vegetation data collection protocols and forms in Appendix A and B. Current methods for controlling cheatgrass are discussed in Chapter 4. A series of different scenarios representing various levels of cheatgrass severity are presented in Chapter 5 to give readers examples of the types of results that may be obtained in different settings.

The decision-support framework (Fig. I-1) describes a series of steps intended to maximize the success of a cheatgrass management program. The framework is based on a set of questions related to the management process. Small, inset circles in the diagram pose these questions (Fig. I-1). Each question may include more detailed, and specific, supporting questions that enable land managers to refine their approach to managing lands where cheatgrass may pose a challenge. The overarching questions and potential supporting questions are as follows:

- **Do I have cheatgrass?**
  - » This simple "yes" or "no" question may be answered by current knowledge or may require a survey of the management unit to determine whether cheatgrass is present. Information regarding positive identification and comparison of cheatgrass to other, potentially similar, grasses is presented in Chapter 1. The next question moves the decision-maker toward a better understanding of the potential impacts if cheatgrass is present.

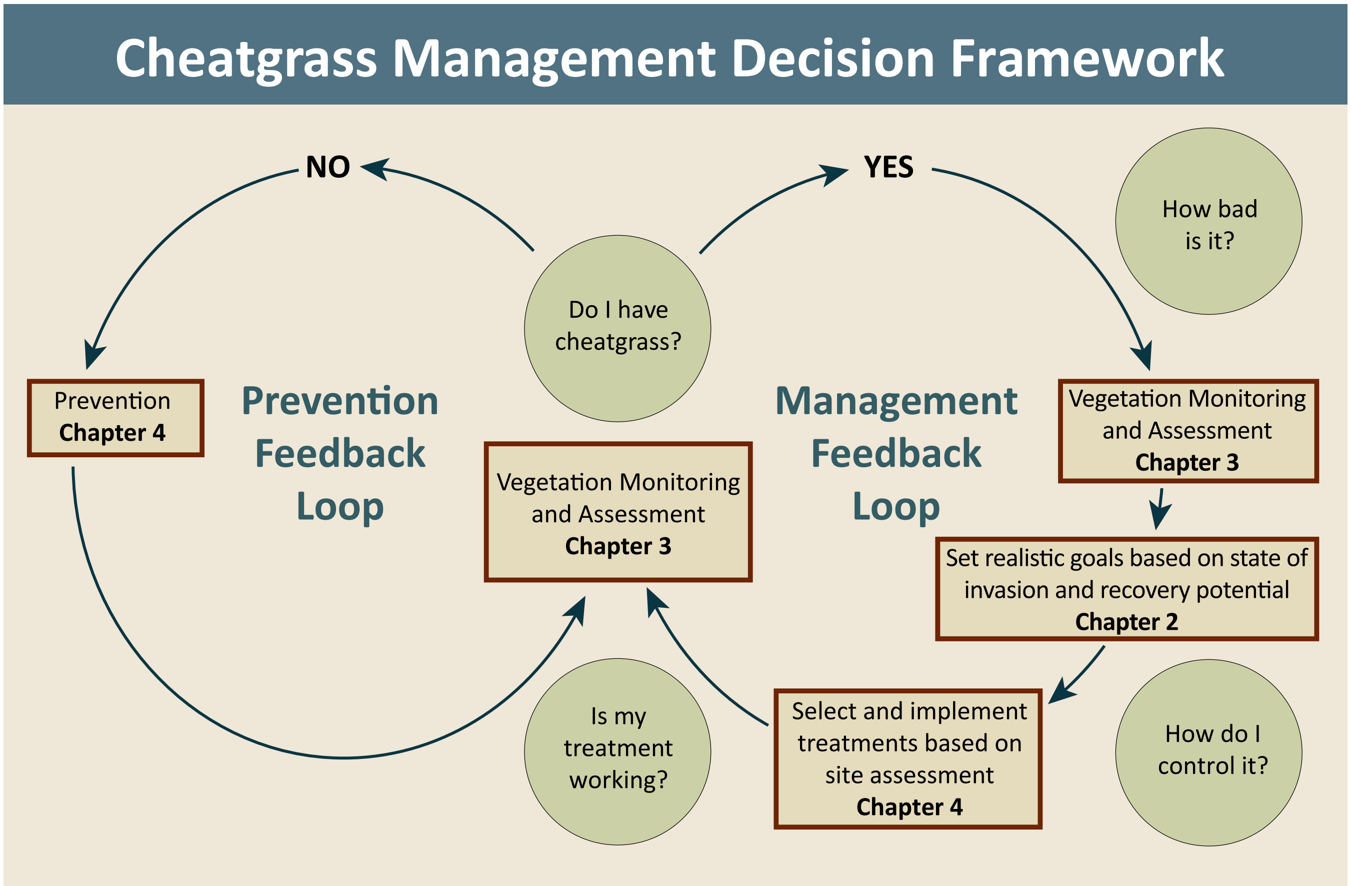

Figure I-1. Cheatgrass Management Decision Framework. This series of steps describes an iterative process to strategically manage cheatgrass in pastures, wildlands, and rangelands. Beginning at the initial question—Do I have cheatgrass?—this decision-support tool walks a manager through the steps described in this handbook. Long-term commitment to vegetation monitoring is a cornerstone, so managers can adequately determine progress toward stated vegetation-management goals.

- **How bad is it?**
  - » The impacts of a specific weed on a system often depend on the management goals for the site and the needs and desires of the individuals who or groups that use the landscape. Chapter 2 emphasizes the importance of understanding perceptions of natural resource issues and how those perceptions may affect land-management goals. Considerations for setting clear goals and objectives for a management plan are also presented. Chapter 3 discusses methods for evaluating the extent and severity of cheatgrass populations and the status of desirable vegetation on the area of interest. Collection of vegetation data is a cornerstone in this management process. Vegetation monitoring allows a land manager to document trends such as increasing abundance of cheatgrass or diminishing production of perennial forage species. Vegetation assessment also provides a gauge of recovery potential on-site: a cheatgrass-infested site with no desirable species may require a different management

strategy than one with little cheatgrass and a high relative proportion of desirable plants. These concepts are discussed at length in Chapter 3.

- **How do I control it?**
  - » Many tactics exist for reducing cheatgrass abundance on pasture and rangelands. Chapter 4 discusses methods for reducing cheatgrass populations, ranging from grazing management to nutrient manipulation to chemical control. Special considerations associated with each method are presented to aid land managers in deciding which method is appropriate for their situation.

- **Is my treatment working?**
  - » Whether a management treatment reduced cheatgrass abundance on a site can be very straightforward: did it work or not? Is cheatgrass still there? The benefits and longevity of a particular treatment, or management strategy overall, are best informed by vegetation monitoring. Chapter 3 discusses long-term monitoring techniques designed to answer specific questions regarding vegetation dynamics—including cheatgrass and associated vegetation.
  - » The cyclic nature of the decision-support framework indicates the need for long-term strategic planning and action to reduce the impacts of cheatgrass on a given site. Single-entry treatments may provide excellent short-term control, but there is no "silver bullet" for cheatgrass. Continued monitoring and evaluation of vegetation resources enable land managers to assess the success of a particular management action—and to adjust accordingly if the site is not progressing toward vegetation goals.

Bruce Bosley, Colorado State University, Bugwood.org

Chapter 1

Biology of Cheatgrass

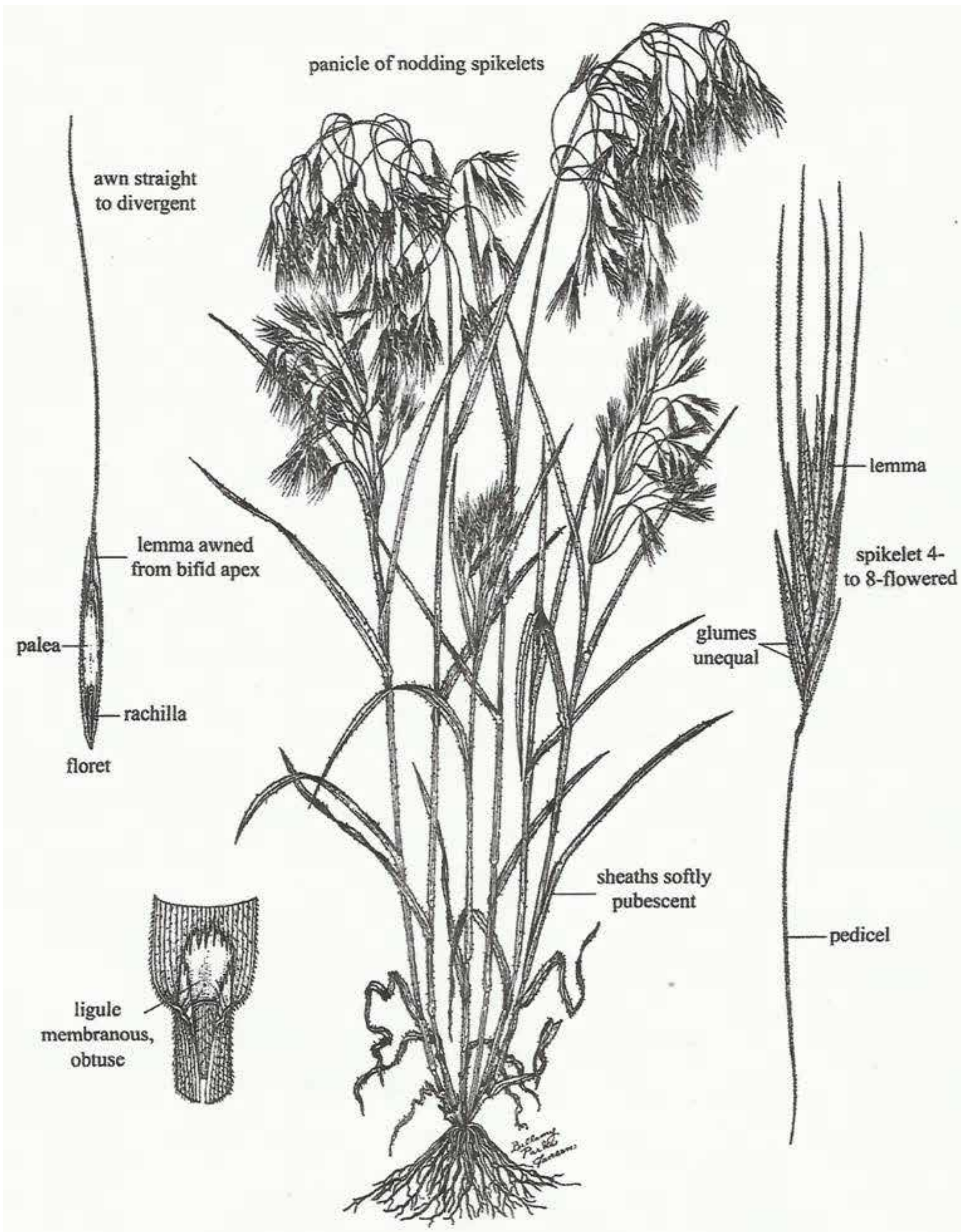

Figure 1-1. Cheatgrass illustration; adapted from Stubbendieck et al. (2011).

Chapter 1 – Biology of Cheatgrass

IDENTIFICATION

Species: *Bromus tectorum* L.

Common Names: Cheatgrass*, cheat, downy brome, drooping brome, junegrass, bromo velloso, broncograss, wild oats, military grass, downy chess, early chess, six-weeks grass, thatch bromegrass[1, 2]

*Referred to in this publication as cheatgrass

Life Span: Winter annual (see sidebar on Annual Grasses, page 7)

Origin: Introduced (from Eurasia)

Season: Cool

Reproduction: Seeds

At a Glance Characteristics: Drooping head; long awns on seeds; matures quickly, turning a purple-red color in the summer (may appear shiny from afar) before curing to a tan-buff color; hairy leaves; roots easily pulled from ground

INFLORESCENCE CHARACTERISTICS:[2, 3]

Type: panicle 2–8 inches long, open, dense, multi-branched, soft, drooping/nodding, often purplish; branches/pedicles slender, flexuous

Spikelets: contain 4–8 seeds and two glumes, relatively large, somewhat flattened

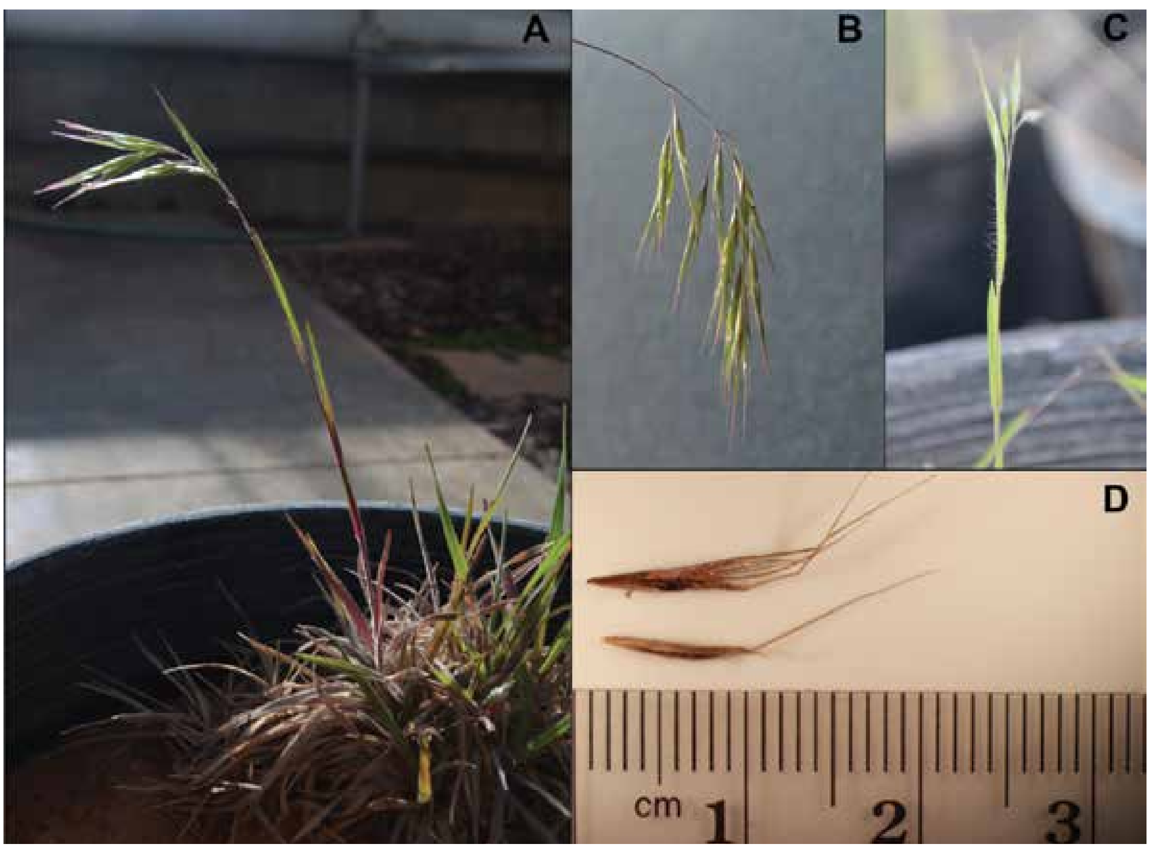

Figure 1-2. A) cheatgrass plant and its identifying characteristics, including B) the inflorescence, C) the pubescent leaves, and D) the floret (top) and seed (bottom).

Seeds:	narrow, lanceolate, glabrous or hairy, 0.8–1.5 inches long; floret rounded on back, 0.4–0.8 inches long; awns straight, 0.4–0.7 inches long
Glumes:	unequal, glabrous or hairy; first glume 0.16–0.28 inches long, one-veined; second glume 0.31–0.43 inches long, three- to five-veined

VEGETATIVE CHARACTERISTICS:[1, 2] (see sidebar on Look-alikes, page 20)

Growth Habit:	solitary or bunch-like; can have as many as 20 tillers per plant
Culms/Stem:	erect or curved and spreading at base; hollow, smooth, glabrous or pubescent, up to 24 inches tall
Leaves:	smooth, softly hairy; leaf blades flat, 1.6–6.3 inches long and 0.07–0.30 inches wide; leaf sheaths round, keeled toward collar
Ligules:	thin, clear, paper-like, torn-edged, 0.07–0.14 inches long
Collar:	smooth, yellow, continuous
Vernation:	rolled
Coloration:	green from germination, turning purple-reddish once seeds are produced, then a tan straw-buff color as they mature and cure
Rhizomes:	none
Roots:	fibrous root system concentrated in the upper 12 inches of the soil

SIDEBAR 1-1: ANNUAL GRASSES

An annual grass is a grass that completes its life cycle (germination, flowering, and seed-set) in one growing season.[3] With such a short period to thrive, a great deal of energy is put into aboveground growth and reproduction. Consequently, many annuals have very shallow root systems and produce many seeds. Perennial grasses, on the other hand, are long lived and usually go dormant during winter before sprouting up again in the spring. Perennial grasses often have highly developed root systems; although this is an evolutionary advantage in some respects, it also contributes to the competitive advantage of cheatgrass.

The Great Basin has a history of invasion by annual grasses, including cheatgrass, medusahead wildrye (*Taeniatherum caput–medusae* L.), and red brome (*Bromus rubens* L.). In 1999, 1.7 million acres of the Great Basin burned due to fine fuels from annuals. These annual grasses had invaded more than 25 million acres. After the fires, managers realized that if something was not done to salvage the Great Basin ecosystem, it could be lost or severely impacted. As a result, the U.S. Department of the Interior's Bureau of Land Management (BLM) developed the Great Basin Restoration Initiative with the objective "to restore plant community diversity and structure by improving resiliency to disturbance and resistance to invasive species over the long term."[59]

GROWTH CHARACTERISTICS:[2] seeds drop in summer; seeds must go through a dry-after-ripening period to lose dormancy; seeds typically germinate in late fall or early spring; rapid spring growth, and then seeds mature about 2 months later; reproduces from seeds; an aggressive weed

LIVESTOCK LOSSES:[2] awns may injure eyes and mouths of grazing animals and contaminate fleece

FORAGE VALUE:[2, 3] fair to good for livestock when green in early spring, but once the inflorescence emerges, forage quality reduces significantly; deer and pronghorn antelope graze cheatgrass in the spring while it is actively growing; furnishes food for some upland birds and small mammals

HABITAT:[2] occupies a wide range of habitats from uplands to riparian zones along with heavily grazed rangelands, roadsides, and disturbed sites; adapted to a broad range of soil textures, most abundant on dry sites; dry plants can be a severe fire hazard

HISTORY AND DISTRIBUTION

Origins and Invasion

Until the 19th century, cheatgrass was known to exist only within its native range—western and central Europe (Austria, Slovakia, and southeastern Germany), northern Africa, and Asia.[4] In its native Mediterranean region in Europe, cheatgrass occupies the decaying straw of thatched roofs. '*Tectum'* is Latin for "roof", hence the name *Bromus tectorum* or "brome of the roofs."[5] Now, cheatgrass has been introduced to every continent except Antarctica.[6, 7] Cheatgrass was accidentally introduced to the United States via contaminated grain or packing material from Europe. In addition, it was purposefully planted by the U.S. Department of Agriculture (USDA) in an attempt to find a more resistant grazing species for degraded rangelands. These experimental plantings and sales by peddlers of cheatgrass were done under the name "100-day" grass.[8, 9] Cheatgrass first appears in the botanical records in 1861 in Pennsylvania, but specimens were not collected in the western U.S. until 1889 in the Pacific Northwest.[8–10] By 1900, the invasive grass was reported in Washington, Utah, Colorado, and Wyoming.[8, 10]

Human activity facilitated cheatgrass dispersal across North America. The railroad system often spread cheatgrass as a contaminant in grain, straw, and manure.[8] Fire caused by trains allowed established populations to advance outward from railroad rights of way[11, 12] (see Ecological and Economic Impacts for more discussion on cheatgrass and fire). Increased winter wheat cultivation also aided in the establishment of cheatgrass. Winter wheat and cheatgrass have similar growth patterns so planting cycles and practices favoring winter wheat also favor cheatgrass.[8] Migratory livestock, and perhaps wildlife, dispersed cheatgrass as well (see Seed Production).[8, 13] By 1915, cheatgrass existed in large populations and could be found in nearly every state of the contiguous United States. The ability for cheatgrass to establish in rangeland systems is attributed to previous habitat modifications. These include mining and historical overgrazing in the Intermountain West.[8, 14] The agricultural depression in the 1920s, which resulted in abandoned farmland and deteriorated rangeland, also facilitated the spread of cheatgrass.[8, 9, 14] Even without prior disturbance from land uses, cheatgrass can easily fill open niches. For example, areas such as the Great Basin lack a native dominant annual grass, which can allow cheatgrass to establish and even replace perennial bunchgrasses. Climate similarities between the Intermountain West and the native range of cheatgrass also provided favorable conditions for the spread of cheatgrass throughout our region.[8, 13]

As its populations grew, so did its notoriety as a problem species.[8, 9] In 1936, the term "cheatgrass lands" began to appear.[8] Cheatgrass has only continued to increase in distribution since.

Current Distribution

Today, cheatgrass infests every region of the United States and has an estimated historical annual spread rate of 14 percent.[15] Sources report that cheatgrass now infests more than 101 million acres.[8, 16] While a major concern in the western United States, it is mainly a roadside weed in the eastern portion of the nation.[17] It is estimated that global climate change could increase cheatgrass abundance throughout the West. Vegetation types most at risk in this region are shrublands and grasslands.[18] Changing temperature and precipitation are likely to shift suitable cheatgrass habitat northward and increase risk in Idaho, Montana, and Wyoming whereas areas in southern Utah and Nevada may become less suitable habitat. Unfortunately, red brome (*Bromus rubens* L.), another exotic, invasive, annual grass, may fill in areas in the southern Great Basin that become too warm for cheatgrass.[18]

Cheatgrass in Colorado and Wyoming

Cheatgrass is native to the sagebrush steppe communities of central Asia. Wyoming and Colorado, also home to sagebrush steppe, possess many ecological similarities that probably contribute to the success of cheatgrass.[12, 19] Colorado places cheatgrass (under the common name "downy brome") on its C list of noxious weeds. Plants on the C list are distributed across the state in large enough quantities that it is no longer considered realistic to eradicate the species. Instead, management efforts focus on providing education, research, and biological control.[20] Cheatgrass is present in most Colorado counties.

Wyoming does not list cheatgrass on its noxious weed list, but it is a county-declared weed in Albany, Converse, Natrona, Platte, Teton, and Weston counties. A county-declared weed is considered a detriment to human welfare, and the county possesses legal authority for regulation and management.[21] Cheatgrass is present in all Wyoming counties, but it varies spatially in severity and extent of invasion across the state.

COMPETITIVE ABILITY

Cheatgrass is a successful invader in the Intermountain West for a variety of reasons. First, it easily occupies sites where soils and vegetation have been disturbed, such as those affected by overgrazing, natural resource extraction (i.e., energy and minerals), the development of rural subdivisions and other infrastructure, road building, or fire. Second, cheatgrass is adapted to a broad range of soil textures. Third, its long, sharp awns make it easily transported by animals of all kinds, and these same awns defend the plant against herbivory. Finally, it is able to fill the niche of a dominant cool-season annual grass, especially in areas where native cool-season annual grasses are lacking. However, the characteristic that may contribute most to the success of cheatgrass involves "phenotypic plasticity."[22] Phenotypic plasticity is the ability of a plant to alter its form (morphology) and the way in which it functions (physiology) in response to changes in environmental conditions.[23]

Specifically, cheatgrass competes easily with native sagebrush steppe vegetation for moisture, nutrients, and sunlight. It does so by its winter and early spring growth habit, and its extensive and fast-growing shoot and root system. Germination of cheatgrass also occurs at a much quicker rate than most perennials.[24] Development of extensive root systems at cold temperatures gives this plant an advantage of exploiting moisture early, while native perennials are still dormant. Where cheatgrass is present, it can use a large proportion of soil moisture, thus making the subsequent establishment of other desirable plant species difficult.

Because of its early phenology, cheatgrass matures and dries out long before native perennial species.[9] This means that, in addition to competing with native vegetation for space and resources, cheatgrass acts as a fuel source for wildfires. Once a cheatgrass stand burns, seedlings easily re-colonize by immigrating from surrounding unburned cheatgrass stands or from the soil seed bank in the burned area. Cheatgrass fires can also pave the way for other exotic species to invade and establish at the disturbed site.[25] Since the invasive can outcompete native seedlings at a disturbed site, fire can lead to a positive feedback cycle of increased fire frequency and increased dominance of cheatgrass.

The time between cheatgrass maturation and seed set is very short. This means that there is a small window of opportunity for grazing animals to utilize the grass. Once seed has set, cheatgrass awns make the grass less desirable forage. Domestic animals and wildlife act as a major vector for seed transportation as the long awns easily get caught in fur or hair.[12] Cheatgrass seeds are not often eaten by livestock or wildlife, and this lack of top–down population regulation could contribute to its success if its seeds are left untouched and those of native species are consumed.

LIFE CYCLE (PHENOLOGY)

Germination and Establishment

Germination and establishment of cheatgrass seedlings vary from fall to spring, making it either a winter or spring annual grass. Cheatgrass, though, is generally considered a winter annual. The grass reproduces by seed and relies upon its seed bank to sustain its population from year to year. Germination of these seeds depends upon environmental conditions, especially precipitation. Summer or early fall rains cause rapid germination, but good fall growth requires approximately 2 inches of well concentrated rainfall.[10, 24] A single cheatgrass stand may consist of plants from multiple germination events. This asynchronous germination and emergence may make management methods with highly specific timing requirements difficult to implement. Once germination of a given seed begins, it will be completed within 2–5 days.[24] Litter cover and soil surface depressions enhance cheatgrass germination compared to a bare or smooth soil surface (Fig. 1-3). Rough microtopography creates favorable microclimates with increased moisture and temperature.[26, 27]


Beth Fowers

Figure 1-3. Cheatgrass seedlings emerging under litter layer.

Growth

If cheatgrass germinates in the fall, it grows until conditions become too cold. Then, it overwinters as a seedling but still expands its roots during winter.[24, 28] Although cold temperatures can limit cheatgrass growth and establishment at high elevation (some estimates suggest 10,000 feet as an upper elevation limit), cheatgrass is considered very cold tolerant, and only a small percentage of individuals die in the winter.[29–31] It renews rapid growth when spring brings warm temperatures, and growth continues until conditions of low soil moisture. [24, 32] In years of average precipitation, cheatgrass grows to a height of 10 to 20 inches. Above-average precipitation can allow cheatgrass to grow to a height of 24 inches while below-average precipitation can limit growth to 2 to 3 inches.[9]

Seed Production and Maturation

The boot stage (formation of grass spikelets) usually begins in May or when soil moisture is low. Cheatgrass normally self-pollinates; however, disturbances that make additional resources (water, nutrients, and light) available to cheatgrass or reduced cheatgrass density can induce cross-pollination. These cross-pollination events result in greater genetic diversity that could produce competitive cheatgrass individuals adapted to new microclimatic conditions.[19, 33, 34] Cheatgrass is a prolific seed producer but exhibits extreme variability in the amount of seed produced per plant. About half of the individuals in a cheatgrass population will only produce six seeds or less, but a single individual has the capability to produce more than 500 seeds.[30, 31] Cheatgrass can produce seed densities of 446 to 1,190 seeds per square foot in, or on, the soil.[35] Remarkably, plants under moisture or grazing stress that only grow 2 inches tall can still produce seed.[9] Seed production is mainly dependent on precipitation and cheatgrass density at a given site. At lower cheatgrass plant densities, more seeds and plant biomass are produced per individual plant.[9, 29, 36]

Beth Fowers

Figure 1-4. Cheatgrass color change in late spring/ early summer.

Shayla Burnett

Figure 1-5. Dispersal of cheatgrass seeds by animals: both domestic (pictured) and wild.

In late spring or early summer, cheatgrass matures, ceases growth, and turns a purple-reddish color (Fig. 1-4).[10, 24] Please note, however, that a purple color can also occur following stress such as a sudden temperature drop or drought. Thus, the plants may be purple tinged during the winter months. This color disappears if more favorable conditions occur or the plant dries out to yellow.[10] Seeds ripen and fall onto the ground shortly after the purple-red stage in the late spring or early summer months.[10, 24] Animals may disperse the seeds because the awn readily attaches to hair, fur, and wool (Fig. 1-5), and seeds may be viable after passing through the digestive system of cattle.[8, 37] Otherwise, seeds may be dispersed less than 3 feet by wind.[14] Following fire, increased wind speeds due to lack of vegetative and litter obstruction may increase this distance to nearly 7 feet.[38]

Seed Bank and Seed Viability

Cheatgrass seeds are not completely mature when they initially fall to the soil surface. Seeds must first endure a dry after-ripening period that may last up to several months. By fall, seeds are completely mature and non-dormant.[39, 40] Seeds are reportedly viable in the soil for two to three years,[7] but it is difficult to accurately determine how long seeds remain viable under natural conditions in various types of soil. Cheatgrass does not establish a long-term seed bank.[29, 30] The seeds have almost a 99-percent germination rate very soon after maturity, and most will germinate in the first year.[24, 29, 30, 39, 41] If they do not germinate, seeds may not persist in the seed bank two years after falling from the plant. After four years, the germination rate of the seeds drops drastically—to less than 4 percent.[39, 42] Certain conditions can promote longer survival of seeds. Burial to depths of 8 inches can lengthen viability to four years.[42] Under laboratory storage, seeds can remain viable for up to 11.5 years.[29, 30]

Litter Accumulation

Cheatgrass normally dries out one to two weeks after reaching maturity due to a very low moisture content[10] and is, consequently, a prolific litter producer. It averages an air-dried yield of 200 pounds per acre of litter with a documented range of litter production from 118 to 293 pounds per acre.[43] Cheatgrass-dominated areas accumulate greater amounts of litter residue, sometimes resulting in a completely litter-covered surface.[9, 44] For example, a study of native perennial grass communities in Utah documented more than 125-percent increases in litter production in cheatgrass-invaded areas compared to non-invaded communities.[44] Once cheatgrass plants senesce (the growth phase in a plant from full maturity to death), the cheatgrass life cycle is complete and reoccurs as new seeds begin to germinate the next fall.

Ecological and Economic Impacts

It is difficult not to admire the competitive abilities and evolutionary success of cheatgrass. These abilities, however, come with both ecological and economic consequences. Cheatgrass infestations can have significant impacts on both the physical environment and other organisms, and, as a result, the interactions within an ecosystem. We rely on healthy ecosystems to provide services such as clean water, recreation, and forage for livestock and wildlife. As ecosystem services provide economic benefits, ecological impacts often cause related economic impacts. Although some could be viewed in a positive light, most impacts are negative. Here, we provide an overview of impacts to native vegetation, followed by the interaction of cheatgrass and fire, and the role of cheatgrass as forage for both livestock and wildlife. Finally, we briefly discuss economic impacts.

Cheatgrass and Native Vegetation

Overall, one of the greatest problems cheatgrass can cause is the displacement of native perennial grasses and shrubs.[11] As an annual, cheatgrass exerts strong competitive pressure on native perennial grass seedlings by germinating early and growing rapidly. Cheatgrass also thrives at disturbed sites. Disturbance provides open niches, which facilitate the dominance of cheatgrass.[45, 46] Once cheatgrass gains a foothold, it is capable of out-competing native species and forming near monocultures (areas largely composed of one species).[11, 13] Monocultures decrease plant diversity and have been shown to result in higher nutrient losses from the system and reduced productivity.[47] This is just one reason that the transition from a native perennial to a cheatgrass-invaded community is less than desirable. Although cheatgrass monocultures are stable in that they are difficult to remove, they could also be thought of as a less stable system because of high inter-annual variation in forage production and the potential for increased fire frequency. The following sections address the profound effects of this altered system in terms of wildfire, forage, and economics.

Cheatgrass and Fire (Fig. 1-6)

Over the years, researchers have recognized a distinct relationship between cheatgrass and fire. They have found that cheatgrass infestations increase fire frequency and extent as well as overall erosion potential after wildfire.[13, 48] When fires burn, cheatgrass invades quickly and displaces native perennials.[13] In addition, increased cheatgrass cover results in increased fire risk due to the build-up of fine fuels.[48] In other words, more cheatgrass leads to a higher

Figure 1-6. Cheatgrass fire.

risk of fire where fire perpetuates cheatgrass, and more cheatgrass, in turn, perpetuates potentially larger fires and more frequent fires.

When cheatgrass dominates a sagebrush understory, there is an increased fire risk because of the increased quantity and continuity of highly flammable fine fuels in the sagebrush understory. In a sagebrush steppe ecosystem, more frequent fires caused by cheatgrass lead to a reduction in the abundance—or even complete loss—of sagebrush.[9] Cheatgrass fires also result in loss of total plant diversity.[49] If a fire does burn sagebrush, the sagebrush community may take 25 to 50 years or more to recover. Since cheatgrass is an annual, it recovers quickly, giving it a competitive edge over the slow-growing sagebrush.

The loss of a significant amount of vegetation to a cheatgrass fire results in exposed soil and reduced soil stabilization. Without vegetation to provide cover and living root systems to bind soil particles together, soil is prone to wind and water erosion. One way to consider cheatgrass in a positive light is as a soil stabilizer. Cheatgrass can produce enough root mass and litter to hold soils in place in what otherwise would be a degraded system. This is assuming that grazing is well-managed and fire is absent.[9, 50] In this way, cheatgrass is part of yet another cycle: it provides soil stabilization in degraded areas, but it also increases the risk of erosion because of the increase in fire risk.[51]

Cheatgrass as Forage and Effects on Habitat

Cheatgrass can provide good forage for livestock in the spring[52] before it produces seed. There are some land managers who find cheatgrass useful as forage and even those who prefer to keep it on their land for this purpose. Cheatgrass, however, is considered an unreliable forage.[9] Cheatgrass production fluctuates greatly from year to year depending on moisture, and it produces less forage overall than native perennials.[52] One study found that introduced wheatgrass produced less biomass than cheatgrass in a wet year but far more than cheatgrass in a dry year.[24] This exaggerated response to moisture compared to natives is one reason cheatgrass is such unreliable forage. Perennials have more consistent production because they are better at exploiting moisture from deeper in the soil profile, if it exists, than cheatgrass.[53] Another potential problem in providing cheatgrass as forage is that the grazing window is short.[9] Once it has matured, cheatgrass is not only inadequate in nutrients but can also be damaging to livestock.[50] Seed awns ingested by livestock can cause "lumpy jaw" (abscesses).[50] Fire is another inherent risk in depending on cheatgrass as forage. There is a possibility of losing valuable winter range forage, plant diversity, and habitat for wildlife—including threatened and endangered species—if a fire breaks out in a matured and dried cheatgrass pasture.

The effects of a cheatgrass infestation on wildlife include both reduced habitat and forage.[13, 52] In cheatgrass-dominated areas, wildlife species such as Rocky Mountain elk must rely on dead cheatgrass, which loses much of its nutritional value when it dries.[9] At least one study has found that cheatgrass can make up a significant portion (about 21 percent) of the diet of elk in winter and spring.[54] Since wildlife can spread cheatgrass populations via fecal matter, [54] this high utilization by elk is a red flag for land managers. This allows cheatgrass to easily invade undisturbed areas, making it important to be alert to cheatgrass presence and arrival, no matter the current condition of your land. As diverse perennial communities become converted to annual grasslands, other native animal species, such as sage grouse and Brewer's sparrows, lose their habitats. Loss of sagebrush and other perennial plant species means loss of habitat for sagebrush obligates, such as the greater sage-grouse, Gunnison sage-grouse, and pygmy rabbit.[55] Raptors and other wildlife can also be threatened because of the decreased ability of cheatgrass-dominated areas to support rodent populations.[56]

Economic Impacts

Major economic impacts are associated with cheatgrass invasion. On rangelands, perennial species that provide high nutrition and year-round forage are replaced by cheatgrass, which is used only sparingly by livestock. Although cheatgrass can provide good nutrition during its early stages of growth, the window of palatability is often narrower than native perennial grasses, and year-to-year forage production varies widely. This causes a significant cost in forage quality and quantity. The cost of cheatgrass management and loss of wildlife habitat must also be considered. Restoring cheatgrass-infested ecosystems can be very expensive, especially when one considers the cost of herbicides (and related application) and seed mixes (and related planting), etc.

A combination of management treatments may be best for restoring cheatgrass-dominated areas, especially when cheatgrass abundances change from year to year.[57] This need for multiple treatments implies increased costs to manage cheatgrass. Another cost concern is the increase in fire frequency and size that can result from cheatgrass infestation. Both fire suppression and rehabilitation require large financial and resource inputs.[56] In 2012, the agencies within the U.S. Department of the Interior combined spent nearly $466 million on fire suppression,[58] some of which were undoubtedly cheatgrass-related fires. Additional cheatgrass costs are associated with damage to human life, property, and other commodities, especially when fires approach the wildland/urban interface.[6]

CONCLUSION

You should now have a good idea of how to identify cheatgrass, what makes it such a successful competitor, and why it is a problem. In this section, we covered vegetative and growth characteristics of cheatgrass and provided information to assist in field identification. We walked through the history, distribution, and spread of cheatgrass and took a detailed look at its life cycle, from germination to senescence. Finally, we offered insight as to why this annual grass is such a competitive invasive species and the potential impacts that could result from cheatgrass infestation. The next step is to determine the goals you have for your land or the land you are managing or helping to manage. Clearly defined goals will be your guide through assessment, management, and monitoring of the land for cheatgrass.

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SIDEBAR 1-2: CHEATGRASS LOOK-ALIKES

Cheatgrass falls into the genus *Bromus* (sometimes known as "bromes") with a number of other species, both native and non-native. Bromes evolved in areas with wet, mild winters and hot, dry summers.[60] One defining characteristic of bromes is their large spikelets. In many cases, these spikelets nod over at maturity, perhaps due to their size and weight. Many of the bromes are fairly distinct from cheatgrass; however, some of these bromes as well as grasses outside of the genus *Bromus* could be confused with cheatgrass. It is important to recognize the specific characteristics of cheatgrass, especially considering that some bromes are native and many are not as harmful. Once you have developed a good sense of what cheatgrass looks like and you have observed it in the field in different settings, it becomes fairly easy to distinguish. Below are some examples of grass species that may trick you into thinking they are cheatgrass.

Joseph M. DiTomaso, University of California, Davis, Bugwood.org

Field (or Japanese) brome (*Bromus arvensis* L.): Invasive annual brome. It could be mistaken for cheatgrass due to its similar brome characteristics, and it is also present in the Rocky Mountain region. The leaves of this cool-season grass are hairy, similar to cheatgrass. The seed heads are much thicker than cheatgrass with multiple awns protruding in multiple directions (twisted and widely spread at maturity). Like cheatgrass and some other annual grasses, it is easier to pull out of the ground compared to most perennials and some annuals. (Fig. 1-7)

Brian A. Mealor

Bulbous bluegrass (*Poa bulbosa* L.): An invasive perennial grass that is less prevalent. Although it is not quite as easily mistaken for cheatgrass, the inflorescence can have a similar nodding and wispy or spiky appearance. It grows from basal bulbs and reproduces from bulblets (tiny grass plants rather than seeds). It will be harder to pull out of the ground than cheatgrass. (Fig. 1-8)

John M. Randall, The Nature Conservancy, Bugwood.org

Red brome (*Bromus rubens* L.): An introduced winter annual. It is not currently thought to be in Wyoming or Colorado, but it is present in other areas of the Rocky Mountain region. The leaves are hairy, but the inflorescence is much more dense and does not droop. It is reddish-purple when mature and has multiple awns per seed head. (Fig. 1-9)

SIDEBAR 1-2: CHEATGRASS LOOK-ALIKES

Shayla Burnett

Sixweeks fescue (*Vulpia octoflora* (Walter) Rydb.): A native annual. This grass has a very short stature, and the inflorescence sticks straight up. Awns are short and numerous. Seed heads are connected directly to the stem rather than hanging on branches like cheatgrass. (Fig. 1-10)

(http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=VENDUB)

Ventenata grass, also known as North Africa grass (*Ventenata dubia* (Leers) Coss.): An introduced annual grass. Appears very similar to cheatgrass with a branched, drooping inflorescence and awns protruding from the seeds. Unlike cheatgrass, which has straight awns, ventenata grass has bent, or recurved, awns. The inflorescence is yellowish-brown to yellow in color. (Fig. 1-11)

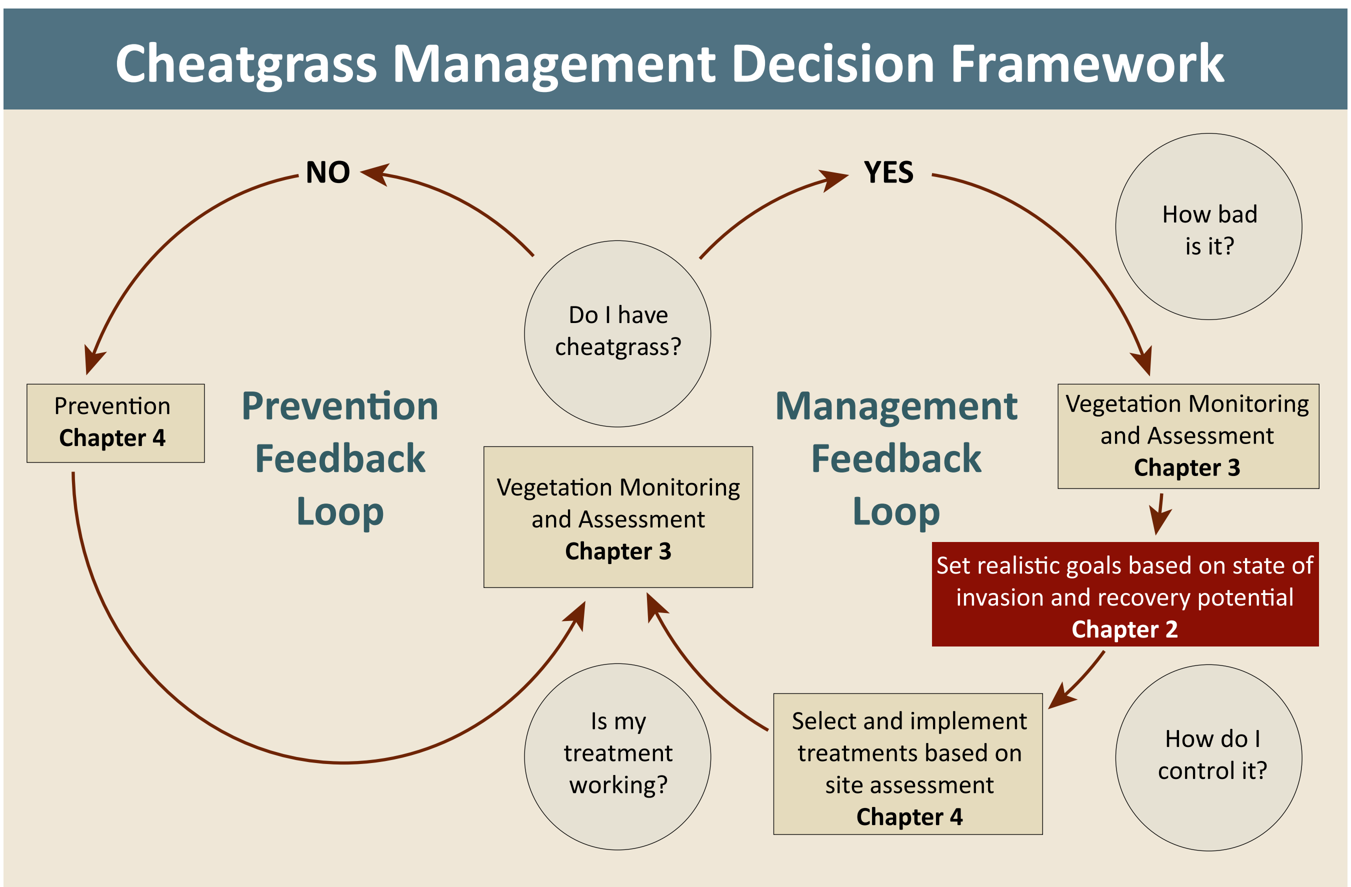
Steve Dewey, Utah State University, Bugwood.org

Medusahead (*Taeniatherum caput–medusae* (L.) Nevski): An introduced winter annual grass. It may grow up to 2 feet tall and has stiff awns that may be up to 4 inches long. The awns have fine barbs making them very rough to the touch. Unlike foxtail barley or bottlebrush squirreltail, medusahead retains its long awns through winter. (Fig. 1-12)

Rachel Mealor

Chapter 2

Understanding Land Manager Perceptions of Cheatgrass, and Setting Management Goals and Objectives



Chapter 2 – Understanding Land Manager Perceptions of Cheatgrass, and Setting Management Goals and Objectives

When the decision is made to manage cheatgrass, developing a management plan is necessary. Developing such a plan will create a road map from the current situation to the end goal for the site. It will also identify available resources, treatment options, and timeframes (whether to reseed, when to spray herbicide, etc.) to achieve those management goals. A basic understanding of the biology and ecology of cheatgrass and the management strategies available are needed to devise a clear plan. However, the long-term, successful management of cheatgrass must also include understanding how humans fit into the picture.

You will be more prepared to develop management goals, strategies, and a plan if you seek out and understand what individuals (neighbors and beyond) and organizations in your area know and believe about managing invasive weeds and their values and attitudes toward natural resource management. Considering potential cooperators or partners is particularly important in areas of mixed landownership, where two or more private landowners are involved, where private and public lands are intermingled, etc. Do landowners, land managers, and the general public know about cheatgrass? Do they understand what an invasive weed is and the potential consequences if cheatgrass dominates the landscape? Are there people in the (proposed) management area whose sensitivities to the use of chemicals (natural or synthetic) need to be considered when developing a management plan and strategies? These are among the questions worth asking to provide information toward the development and implementation of a management plan.

The success of a cheatgrass management plan also includes understanding current conditions and the ecological potential of the site. This information can be used to develop realistic, measurable goals to maintain or achieve the desired condition. Knowledge of your land's current condition helps to assess, through time, whether or not a management strategy is effective, or if a new approach should be considered. It might be thought that understanding and incorporating human dimensions of invasive weeds into a management plan and developing meaningful goals is too time-consuming. However, this initial investment has the potential to pay off many times over. This chapter will discuss human dimensions and integrating them into a management plan. You will also read about different types of goals, considerations for developing goals, and how to accomplish those goals.

HUMAN DIMENSIONS

The human dimensions of managing weeds are very important to any management program. What are human dimensions? Human dimensions are individual or group values, interests, and perspectives about socio–economic, political, and ecological topics. For example, we intuitively recognize that people who live on the land and depend on it for their livelihoods may have different views about its ecology and management than people who primarily interact with the land as a scenic backdrop or place to recreate.

Why is it important to consider human dimensions when managing weeds? Our knowledge and perceptions about cheatgrass influence our decisions about whether (and to what degree) to invest time and money to manage the species. For example, some people are not familiar with cheatgrass; they may or may not have an interest in managing the plant once they learn about its invasive potential.

Alternatively, a person may have literally been exposed to cheatgrass—but does not know the name of the plant that lodged itself—in a very irritating way—in his or her socks. If they do not understand the ecological impacts of cheatgrass, they might be more likely to make decisions based on economic trade-offs alone. In other cases, people know and are familiar with cheatgrass because it has displaced the desired grasses in their pastures and rangelands. Some of these people may have a clear idea of how to manage cheatgrass on their lands, while others may not be familiar with management approaches. You can imagine a number of other perceptions people might have about cheatgrass. Regardless of your own perceptions, it is important to know how your neighbors, agencies, organizations, and others perceive cheatgrass. It is also important to understand the factors that influence whether or not these groups make a decision to manage cheatgrass (Sidebar 2-1), and how they choose to manage it.

SIDEBAR 2-1

There are many decisions to make when designing a cheatgrass management plan, especially when success is partially based on the involvement of different individuals or groups of people. If this is the case, it is helpful to understand the process people go through when deciding whether they will try something new (i.e., adopt an innovation). What is an innovation? An innovation is generally a new idea, practice, or technique developed to address a problem or meet a need.[4]

Prior research suggests five characteristics that make an innovation more adoptable. These findings can be used to help you develop a strategy that might encourage your target audience(s) to manage cheatgrass. The five characteristics are:

1. **Relative Advantage:** benefits of adopting an innovation compared to the prior practice
2. **Compatibility:** the degree to which an innovation is consistent with existing values, past experience, and needs
3. **Observability:** the degree to which results are visible to potential adopters
4. **Trialability:** the degree to which an innovation has been tested
5. **Complexity:** the degree of difficulty to understand the innovation and/or the development of new skills

Innovations that are less complex, but have greater degrees of the other four characteristics (1–4 above), tend to be adopted first.[4]

Incorporating Human Dimensions Into Your Management Plan

When developing a weed management plan, it is important to include a section about the human dimensions. To do this, you will need to gather sufficient information. Learning about attitudes and perceptions of invasive plants and their management is a growing field of study (Sidebar 2-2). Although more studies and information about the human dimensions of invasive weed management are being published and made available, it is important for land managers—both private and public—to invest time to understand what individuals and organizations in your area know and believe about managing invasive weeds. There are three basic steps to follow to better understand the human dimensions of individuals or organizations. These, which will be discussed below, include: 1) Define and identify your intended audiences(s); 2) Develop questions; and 3) Determine the strategy and mode to collect information.

The first step is to identify and define your intended audience(s). Audiences could include private landowners, grazing permittees, private land lessees, neighbors, recreationists, energy development companies, government land-management agencies, weed and pest control districts, conservation districts, etc., or some combination of these. For example, you might define your target audience as landowners with a minimum of 10 acres in the Boulder Subdivision and the county that maintains the road and rights-of-way. You could further define your target audience by including parameters such as landowners with at least 10 contiguous acres.

The second step is to identify what information you want to know, and develop appropriate questions to obtain that information. Seek answers to help you throughout the process of developing and implementing your weed management plan. There are a number of questions that should be answered to more effectively work with private landowners, including neighbors, or to manage public lands, particularly for multiple-use (Sidebar 2-1).

The third step is to develop a strategy for acquiring the desired information. If you are a private landowner, consider having coffee with your neighbors so you can begin an informal, friendly conversation about weed management. If you work for an agency or organization, you will likely invest in a more formal process to learn your constituents' perspectives, which could include hiring a professional organization to design and facilitate the assessment. For example, you might consider developing a survey (e.g., mail, online, over the phone, etc.) or facilitating a focus group (a homogeneous group [typically around 6–12 individuals] that participates in open dialogue). You will want to consider available resources, such as work hours and money, when assessing which strategy to use to gather the information. You should gain the consent of participants if you gather information through an interview or focus group.

The following information and the information in Sidebar 2-1 should provide you with a basic framework of recommended questions to understand some of the human dimensions about cheatgrass.

- Are people able to identify cheatgrass? You could ask the question by showing several different grasses that occur in the area, including cheatgrass. The respondent would

SIDEBAR 2-2

Steve Dewey, Utah State University, Bugwood.org

The following discussion offers you an understanding about land manager (i.e., ranchers and natural resource professionals [NRPs]) perceptions and management of cheatgrass. Additionally, this information illustrates the importance of understanding human dimensions, such as values, perceptions, and knowledge of socio–economic, political, and ecological topics, of your target human population.

In 2009, a study was implemented to understand land manager perceptions and management of cheatgrass in Colorado and Wyoming.[5] Both ranchers and NRPs perceived cheatgrass as an issue to some degree throughout both states. The study found that the perceived severity of cheatgrass largely paralleled the level of infestation in the respective region. The following are conclusions from Kelley et al., 2013.[5]

Perceptions differ between populations:
NRPs perceived cheatgrass as a greater problem than ranchers from the same region except in southeastern Colorado. Comments by some ranchers highlighted the value of cheatgrass for early spring livestock forage.

Management strategies:
NRPs were most likely to use seeding, an imazapic-based herbicide, or a combination of methods (i.e., prescribed fire, herbicide application, and seeding) to control cheatgrass. Their level of satisfaction with control methods depended on the region they were from. Overall, NRPs were most satisfied with a combined approach, or only the application of an herbicide.

Ranchers, on the other hand, were most likely to use and most satisfied with early spring grazing to control cheatgrass. These findings suggest that land managers are more inclined to use the management strategies that are most readily available to them.

Constraints to managing:
Ranchers and NRPs reported that the primary constraint to controlling cheatgrass was that other weeds were a higher priority (e.g., Canada thistle or yellow star-thistle). This could limit land managers' motivation to manage cheatgrass. Land managers reported other weeds were a higher priority because they are listed as state/county noxious weeds, and more funds are available to manage them. Additionally, land managers reported that they have insufficient labor to manage cheatgrass.

be asked to indicate which plant is cheatgrass or to select "I don't know which grass is cheatgrass."

- Consider asking individuals who are familiar with the plant to what degree they consider cheatgrass a nuisance (a scale from "not at all" to an "extreme nuisance").
- You might want to know if they have tried to manage cheatgrass; if so, how and to what degree were they satisfied with the results?
- Other questions you might ask include:
  - » How do they think cheatgrass is spread (all-terrain vehicles; reseeding; wind and water; movement of animals – domestic or wildlife; fire, etc.)?
  - » Are you in favor of the following potential control methods ("Yes" or "No")? (herbicide; burning; reseeding; a combination of herbicide, burning, and reseeding; spring and/or fall livestock grazing; other – please explain).
  - » What resources or information do you need or want to know about managing cheatgrass?

The above list of questions is not exhaustive, but it provides a foundation of questions to consider answering to better understand your audience(s). Please note that guidance on how to develop a survey and analyze the data is beyond the scope of this publication; however, there are a number of resources available to learn more about the processes (Sidebar 2-3).

The end goal is to develop and implement a management strategy that enables you to achieve your management goals and objectives. Working to understand how different individuals, organizations, and social groups perceive, value, and understand cheatgrass—and their decision-making process to treat or not to treat this invasive grass—is vitally important. Often, understanding these perceptions and decisions is as important as understanding the biology of the plant itself.

SETTING GOALS AND OBJECTIVES

In addition to understanding human perceptions, a successful management plan includes understanding the potential of the land and appropriate goals to set along the way. When managing land, it is necessary to have a clear view of what you want the area to look like, the characteristics of the area, and its potential. It helps to write down what you want to achieve when developing a management plan. A clear, written plan necessitates a defined endpoint to aim for and to refer back to during future evaluations. A well-defined vision also provides direction when forming such plans. Developing management goals and measurable objectives should enable you to evaluate how the project is progressing.

A goal should be a single statement that describes a desired end result of the land that does not simply focus on removing weeds. Multiple goals may be set for a specific property. Objectives are links between goals and what will be done to achieve them. Objective

SIDEBAR 2-3

The art and science of survey development, administration, and analysis can be exciting and challenging. We encourage land managers to consult and work with a professional(s) to develop and implement surveys. There are a number of available resources and tools for everyone from the first-time to the seasoned developer to learn more about the survey process. Resources ranging from books, software, and internet and mobile tools have facilitated the ease of survey development by offering examples of their framework and generating the analyses. The following is a modest list of resources for consideration when developing, administering, and analyzing a survey.

Books

Dillman, Don A., Jolene D. Smyth, Leah Melani Christian. (2009). Internet, mail, and mixed-mode surveys: The Tailored Design Method. Third edition. Hoboken, New Jersey. John Wiley & Sons, Inc.

Fowler, Floyd J., Jr. (2002). Survey Research Methods Third Edition: Applied Social Research Methods Series Volume 1. Thousand Oaks, California, Sage Publications, Inc.

Vaske, Jerry. (2008). Survey Research and Analysis: Applications in Parks, Recreation and Human Dimensions. State College, Pennsylvania, Venture Publishing, Inc.

Software

Microsoft Excel: data storage and analysis

PASW Statistics 18 (formerly SPSS Statistics): advanced statistical analysis software

Internet and Mobile Tools

SurveyMonkey®: an online survey tool that provides survey results

iSURVEY: an application for mobile devices (such as iPad, iPod, iPhone, and Androids) that enables data gatherers to electronically collect data face to face or at kiosks. Data are stored in the application and can be exported to several different statistical programs (e.g., IBM's SPSS® Text Analytics for Surveys software).

Contact a university, community college, or other public institution to find local or online courses for more in-depth information and training about survey development, administration, and analysis.

statements are measurable, describe what you want to accomplish, and include an estimated time frame for completion. Examples of goals and objectives can be found in Sidebar 2-4.

Project goals and objectives should be ecologically and economically realistic. They should be written to fit a specific site, not a pre-determined "one-size-fits-all" plan. For example, some areas may be more invaded or damaged than others. If a site is highly impacted by cheatgrass, the necessary economic inputs will be greater and a "pristine" ecological end-point may not be possible. Site characteristics must be well understood to develop realistic goals and objectives. By implementing a pre-treatment assessment, site characteristics such as vegetation densities, degradation (e.g., erosion), high-risk areas (e.g., roads that could serve as vectors for additional seed input), and other environmental characteristics can be determined. Once the ecologic, economic, and spatial considerations of a project are defined, developing achievable goals becomes a more likely prospect.

Ecological Considerations

Setting realistic ecological goals and objectives require understanding the ecological potential of the site. For example, you might desire a pasture that produces 2,000 pounds of forage per acre per year. In reality, a semiarid range site would more realistically produce 600–800 pounds of forage per acre per year. Without understanding the ecology of the system, goals may be set at an unachievable mark. Generally, managers understand the realistic limitations of the systems in which they work. They also understand the possibility of year-to-year fluctuations resulting from a variety of variables (i.e., timing and amount of precipitation). Keeping these site limitations in mind helps in the development of obtainable goals.

Describing and understanding the ecology of your site will help guide the development of realistic goals and objectives. In a situation where the main goal is cheatgrass eradication, the probability of success depends on the current level of cheatgrass infestation. If you have very few cheatgrass plants or a small population, eradication may be possible. However, due to the biology and competitive ability of this invasive, it is unrealistic to transform a cheatgrass monoculture into desirable native grassland using only limited effort and time. Consequently, if your site is at a cheatgrass-dominated level, complete eradication may not be possible and your goals instead should aim to control and reduce cheatgrass density. Prioritization is a way to define where management actions take place on a landscape. Ecological prioritization occurs when high-risk areas or areas more likely to reach a goal are managed first.

Economic Considerations

Creating realistic goals and objectives require consideration of the costs associated with achieving them. These include financial input, time invested, and possible economic returns. A potentially significant economic cost comes in the form of implementing cheatgrass control methods. It is recommended that you identify the economic trade-offs and feasibility of each potential management strategy before making a final decision. If a management strategy is not financially feasible then you can explore alternatives or redefine your overall goal, specific management goals, or objectives. Economic prioritization of land management is used when there is limited amount of time or funds.

SIDEBAR 2-4. EXAMPLES OF GOALS AND OBJECTIVES

Goal 1: Maintain a diverse plant community across wildlife habitats for the next 15 years.

Objective 1: If cheatgrass is found at a moderate level or greater, choose an appropriate treatment strategy to implement until cheatgrass is reduced to a trace level.

Goal 2: Maintain a working and productive ranch so we can pass the ranch to our children.

Objective 1: Within three years, reduce the density of cheatgrass by 80 percent in the west pasture and manage additional populations as they occur.

Objective 2: Apply herbicides and reseed desirable species so that production and diversity of perennial plants increases by one third over the next five years.

Goal 3: Improve rangeland condition across the permit area.

Objective 1: Within five years eradicate all small populations of cheatgrass.

Objective 2: Over three years, increase desirable forage and reduce cheatgrass to a mild level of infestation.

Goal 4: Create and implement a monitoring program.

Objective 1: Annually monitor where cheatgrass may establish to detect new infestations.

Spatial Considerations

Developing realistic goals and objectives also depend on the spatial area where the cheatgrass infestation is being managed. Is the management area a small patch, a few acres, or a large ranch? Considerations of space help to identify potential economic limitations resulting from size, sites that should be prioritized for management, and the management plan that works best for that area. For instance, you may decide an entire ranch is too large to manage at once, leading to the management of only small, prioritized land segments (see Prioritization, Chapter 3). In some cases, eradication of cheatgrass within a small area is still not achievable, even though its management is of high priority (i.e., the area provides water for livestock).

Cheatgrass spread is not restricted by fence lines. In other words, though you can manage infestations within your own land, we all have boundaries we need to work within. In these cases, it can be beneficial to take a landscape-scale approach to management. For example, alignment of your management plan with those of surrounding neighbors, along with agencies and others, provides a greater probability of success because those plans should follow regional laws and will reflect similar or complementary goals and objectives.[1] Alternatively, if a group of land managers agrees on cooperative plans, but one adjoining area is not part of the program, the integrity of the whole is in danger. It is also important to understand that regulations may not be consistent across geopolitical boundaries. If you are working to manage an area that crosses state or county boundaries or abuts them, you may have to try harder to find solutions. This may require more intensive relationship management or engagement of unenthusiastic stakeholders.[1]


Rachel Mealor

Figure 2-1. Discussing rangeland management objectives, 2012.

Creating goals and objectives are unique to each situation. In each case, different individuals will be involved, different site characteristics will be present, and different economic requirements or limitations will exist. Clear consideration of the ecologic, economic, and spatial characteristics involved at your site and in your management area can help define clear goals and objectives. When we understand the realities of our property and the landscape around us, we can identify what exactly needs to happen, leading to more successful management plans.

Accomplishing Goals and Objectives

We discussed earlier that it is important to set clear, realistic goals and objectives. As stated, a goal defines a desired end result while objectives help illustrate the specifics of how to reach that goal. In other words, objectives act as small-scale checkpoints that can easily be redefined to make final goals less intimidating. They can also segment the goal into achievable portions, limiting our attempts to accomplish a large goal all at once.[2] Objectives can help illustrate whether management strategies are effective (e.g., size of cheatgrass population is trending downward) or if a new strategy should be considered. Without setting objectives, you may not see the necessary steps, or you may fail to adjust unsuccessful strategies preventing you from achieving your goal. Consequently, as work toward the goal(s) progresses, there needs to be continual adjustment and evaluation regarding the effectiveness of management.

Opinions, perceptions, and priorities of all involved can influence how your goals and objectives are accomplished (see Human Dimensions section). Identifying and addressing similarities and differences in perceptions early in the planning process helps to develop achievable goals and objectives among stakeholders. Different goals or preferred control strategies may arise, which can lead to conflict.[3] When a management area has more than one stakeholder, untangling desires can be difficult. For example, opinions about a single site could come from a rancher who wants to grow more consistent forage for livestock, a hiker who wants to see native species, and a wildlife biologist with interests in habitat for big and small game, birds, and other species. Each individual has different ideas about what he or she wants the area to look like. Their tolerance or ideas about cheatgrass might vary as well. When conflict occurs, it is important to communicate and explore the possibility of accommodating all interests through negotiation, compromise, and prioritization. Allowing divergent ideas to continue could lead to a universally undesirable endpoint.

In some situations, communication can solve potential problems. For example, imagine that two people want a single orange from a market and proceed to argue about who will get it. Finally, they decide to cut the orange in half to divide it equally between them. However, if the two people had communicated more effectively, they would have realized that they each wanted the orange for different reasons. One wanted the pulp for juice while the other wanted the peel for zest. If they had communicated this to each other, both would have received 100 percent of what they desired. Instead, they ended up with only half of what they wanted.

Negotiation often requires working through conflicting desires. Addressing what each person actually wants through communication can alleviate the need for negotiation altogether. Thus, for multiple groups or individuals to work together effectively, they should communicate clearly and regularly. With clear communication, they can work to set and prioritize goals and objectives. Communication, particularly at the beginning of the planning and goal-setting process, can help ensure that ideas and needs are understood. It can help to efficiently and effectively address problems. Some level of accountability may also be necessary to ensure cooperation and success.[1]

Your goals and objectives should also go hand-in-hand. Land managers who plan out every detail of their objectives will likely encounter unforeseen detours along the way, which could waste valuable resources (time, money, etc.) Therefore, it is important to develop clear goals that define the problem, identify appropriate management actions, and lead to the development of a realistic management plan. Clearly defined and written project goals enable managers to evaluate project success and to adapt their chosen management plan. These goals should always be made with consideration of the complex ecological, economic, spatial, and social systems influencing your land.

CONCLUSION

This chapter discusses the need to understand human dimensions and develop attainable goals and objectives to create a realistic management plan. Land managers of public and private lands must always consider that the public, project partners, community decision makers, and others can influence the long-term success of their project. Therefore, understanding society's values, interests, and perspectives about cheatgrass and its management is imperative. You will likely gain more from your management actions if you take the time to understand the people around you, and leverage their interest in cheatgrass reduction to help mutually achieve your management goal(s) and objectives. Consequently, understanding the human dimensions and setting appropriate goals and objectives are part of the foundation to developing a successful management plan.

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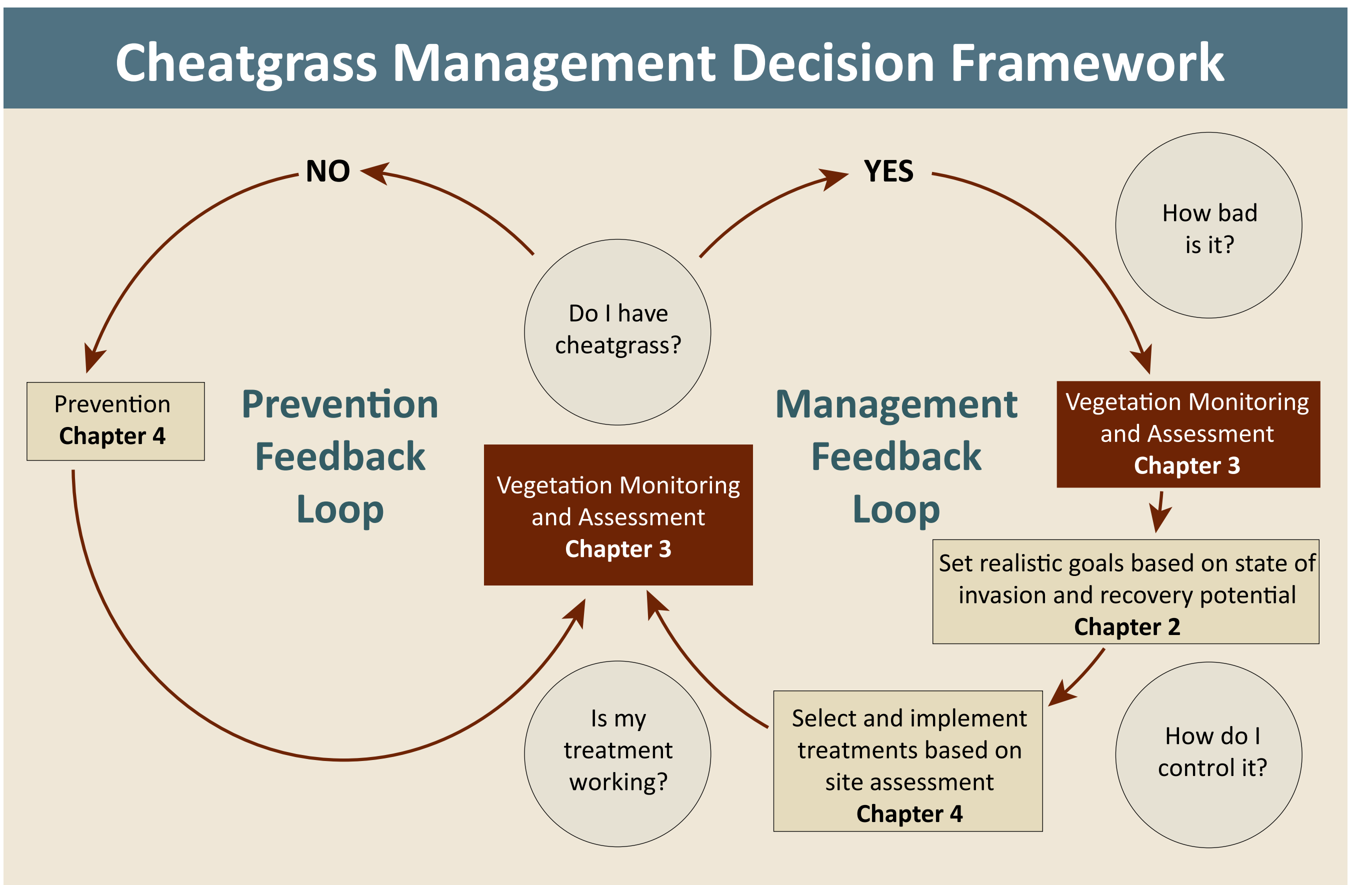
Chapter 3

Assessment and Monitoring



Brian A. Mealor

Chapter 3 – Assessment and Monitoring

THE IMPORTANCE OF ASSESSMENT AND MONITORING

Vegetation assessments are useful in evaluating the species composition and abundance of vegetation at a site. An assessment provides land managers information regarding the condition of the site at that particular point in time, with a focus on the plant community. Monitoring, on the other hand, is the orderly collection, analysis, and interpretation of resource data to evaluate progress toward management objectives.[1] Techniques used to collect assessment and monitoring information are the same in that the completion of multiple assessments over time is monitoring. This information can be used to assess the severity of a cheatgrass invasion and monitor changes within the native plant community. A good monitoring program is a long-term commitment that allows land managers to evaluate trends in natural resource conditions. Here, we explain why performing a pre-treatment assessment and following up with a monitoring program will help you collect critical data and correctly identify a realistic—and budget-friendly—management plan.

COLLECTING ASSESSMENT AND MONITORING DATA

Why conduct a pre-treatment assessment?

There are a wide variety of management options to select from when deciding how to control cheatgrass. Each management method has associated pros and cons. Without completing a pre-treatment land assessment, managers may be likely to develop a management plan that is not suited for their level or type of invasion. Though it may seem unnecessary, completing a simple pre-treatment assessment will help identify the most effective management options. In doing so, you will save time and money that might have been wasted on a less-than-ideal management strategy.

A site assessment may also reveal that no cheatgrass exists within the management area. This means that your assessment no longer precedes any treatment or management; however, discovering that a site does not require cheatgrass control does not mean prevention and regular monitoring are unnecessary.

What is Monitoring?

A monitoring program, as opposed to a pre-treatment assessment, must be conducted over time to determine if the plant communities are trending in the desired direction to meet management goals and objectives. The term "monitor" comes from the root term meaning "to warn." A good monitoring program should be used to warn land managers if vegetation is trending away from stated goals and to provide information regarding vegetation management decisions. The time and effort required to conduct a monitoring program can vary from a single photo point to more labor-intensive techniques requiring annual assessments of each plant species in a community. Because of this flexibility, you can choose how much time and effort you spend on monitoring.

Data collection

All science-based endeavors benefit greatly from consistent and proper data collection. Assessment and monitoring of cheatgrass in a rangeland ecosystem is no different. Collecting data using a chosen method ensures a consistent measure of cheatgrass invasion across your land. The following are four aspects of data collection that every land manager should keep in mind.

First, collect useful information that relates to your goals and objectives. Measure not only cheatgrass cover but also desired vegetation and bare ground. Evaluations of both invasive and native and desirable non-native, cover are important in determining the invasion state and recovery potential of your land. If your management area contains multiple ecosystems or topographic variability, assessments for each area will provide more detailed information on the invasion state across the landscape. Each site and plant community will have variable susceptibility to cheatgrass invasion and react differently to your selected management technique. For example, a low-elevation drainage may have different native plants, recovery potential, and level of invasion than the adjacent upland. When targeting only specific areas of the landscape, data collection in those areas alone is sufficient. When completing an assessment, take note of the site's topography, weather patterns, grazing intensity, and land-use history. Climate and land-use information can be used in evaluating pre-treatment assessments and post-monitoring data analysis. Information about climate and other rangeland-related information can be easily accessed through The Rangelands Partnership (http://globalrangelands.org/rangelandswest) or Colorado Rangelands site (http://lib.colostate.edu/research/corange/index.html) or Wyoming Rangelands site (http://uwyo-extension.org/uwrange/).

The timing of sampling will influence what plants are present and easily identified. A community that supports a variety of plant species should optimally be monitored more than once during the growing season. This can be useful in capturing the presence of cool- and warm-season grass and forb species that may only be easily identified for a short duration during the spring or early summer. If this is not possible, try to monitor at a consistent time of year for clearer indications of changes in cheatgrass and native or desirable species abundance. The appropriate time of year to monitor varies with goals, but plant identification is easiest when the plant of interest begins to flower or develop seeds.

When conducting an assessment or monitoring technique (see techniques below and in Appendix A), increased sampling at many sites provides more precise information about the invasion state of your land. Having fewer sites that you can accurately and consistently assess, however, is better than more sites with incomplete data. Avoid establishing more sites than you have time to assess and monitor, but add sites if time permits. Keep in mind that having easily accessible sites increases the ease and frequency of sampling. Once sites are selected, frequency of assessment depends on the data collection method and the rate at which your land undergoes change. For example, upland sites can be revisited every two to three years, as changes are slow in comparison to riparian areas. Also, photos can easily be taken every year at the same point (photopoint method), whereas more time-intensive methods like point intercept may only need to be evaluated every two to three years. Circumstances causing more rapid changes in vegetation—such as herbicide application, fire, or direct soil disturbance—may warrant more frequent monitoring events.

Second, one of the greatest advantages of assessment and monitoring is the ability to record what vegetation exists on your land or the land you manage at a given point in time. This can be important for current and future management decisions. For example, cheatgrass easily re-establishes after fire, often outcompeting neighboring plants.[2] Consequently, if an unexpected fire were to move through your property, it would be beneficial to implement more aggressive management initiatives on those areas previously affected by cheatgrass. There would be no way to tell where cheatgrass previously existed on your site without past cheatgrass distribution data. Consequently, mapping cheatgrass spread is also a potentially worthwhile assessment and monitoring tool. By compiling a map of your land and indicating cheatgrass invasions, you can document spread or contraction of infestations and locations in case of fire, other disturbances, or management actions. More detailed information on mapping cheatgrass populations is provided below.

Third, non-treated "control" plots are useful when collecting data about direct effects of management actions. These non-treated plots are patches of land under current management (i.e., grazing by livestock or wildlife) that will receive no cheatgrass removal treatment. By comparing control plots to adjacent areas receiving treatment, you can assess the direct effect of your treatment (Sidebar 3-1). Control plots allow you to collect critical information on successful and unsuccessful management decisions for optimal management of that site in the future. In some cases (i.e., when cheatgrass invasion is extremely low and eradication is the goal) it may not be necessary or feasible to use control plots. Working with a control, however, is always a recommended technique if achievable.

Finally, it is important to choose and consistently use the same units with which to make your measurements. Consistently using either the metric or English system of units can save you from tedious conversions later. If you are working with others, agree on which system will be used from the get-go. Also, pay close attention to the sample unit of your chosen monitoring method. For instance, when using the point intercept method, each transect is equal to one sampling unit, as opposed to each measured point being one unit. Though it may seem elementary, forgetting which units you used in the field can be detrimental to your assessment and lead to unnecessary repetition. Many common assessment methods ask the practitioners to measure at unknown scales. You likely have a conceptual idea of these scales, however, and you just need to keep them in perspective. For example, one hectare equals about 2.5 acres and is slightly smaller than two football fields. We can use common references like this to provide perspective to vegetation patchiness. In the end, accurately collected data is paramount. Without it, you have no concrete, objective measure of the past or present cheatgrass and desired vegetation on your site.

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SIDEBAR 3-1. CONTROL PLOTS

We recommend establishing non-treated "control" sites to better understand how your chosen cheatgrass management techniques impact vegetation. Control sites are areas that do not receive any cheatgrass treatment. Why? If the removal treatment is applied across the entire landscape without a control, there is no reference site to help you interpret treatment-caused differences from differences due to other factors (i.e., the environment). Year-to-year variation in temperature, precipitation, grazing pressure, and other factors influence the height and cover of cheatgrass and other plant species. Having non-treated control plots help you decipher the impacts of your treatment in the face of year-to-year variation in cheatgrass and desired vegetation. Control plots also allow any damage to desired species and those species not targeted by the treatment to be evaluated relative to applying no treatment.

Imagine a scenario where you choose to spray Roundup® (glyphosate) two weeks after snowmelt to kill early emerging cheatgrass. This is done consecutively for three years. Each year, cheatgrass cover decreases by 50–60 percent; however, these three years experienced dry winters with little precipitation in early spring. The following year brings a wet winter, and spring rains follow snowmelt. Suddenly, you notice that cheatgrass cover increases by 60 percent compared to the previous year, even with continued application of Roundup. Were your herbicide treatments useless and the reduction of cheatgrass cover due to timing of precipitation alone? Or, would cheatgrass cover be worse if you had not been spraying herbicide? Control plots can help answer these questions. If the control plots have much greater cheatgrass cover, your treatments have been effective at reducing cheatgrass. If cheatgrass cover is similar in both control plots and treated areas, it is likely that your treatment is having little to no effect.

Each control site should be as similar to the area you are treating as possible, with respect to representative habitat type, terrain, soil, topography, and level/density of infestation. This minimizes variability between sites, and it also reduces the effects of external, confounding factors on your treatments. The comparison of dissimilar sites may cause the results to inaccurately reflect the treatment impacts. Once control sites have been selected, permanently mark them so you can continue to monitor the same location over time. Livestock will likely be attracted to permanent posts and stakes. Therefore, if you choose to utilize permanent markers, ensure that they are well anchored. If the area is to be mechanically treated, be sure to make markers visible to both humans and animals. An easy way to establish a non-treated plot, when herbicide is applied aerially, is to lay a tarp down in the area to be sprayed. After spraying, mark the corners of the tarp with stakes and then remove the tarp.

ASSESSMENT AND MONITORING TECHNIQUES

As discussed in the previous chapter, individuals will have a unique set of priorities and goals for their land. Taking on the responsibility of that land's management requires a time commitment. Aside from the management techniques themselves, time must also be spent assessing and monitoring native and invasive vegetation. Here, we provide techniques to evaluate vegetation with time commitments ranging from hours per year to more intensive techniques requiring more time (see Appendix A). For example, though it provides limited information, it takes very little time to snap a photograph of your cheatgrass invasion. On the other hand, creating a highly replicated point intercept system takes longer, but it will provide useful quantitative data for that site. With such a wide range of options, assessing your land may not be as daunting as previously imagined. The time spent on an assessment and monitoring program should provide a more clear strategy for managing cheatgrass.

Though many methods exist to determine the severity of a cheatgrass invasion, some land managers may choose to do nothing. They choose to not gather information because assessment and monitoring seem too time consuming, the invasion is too large, or cheatgrass is not yet recognized as a problem. However, it is clear that some form of assessment is necessary to correctly identify management techniques. Other land managers may choose to implement no management plan at all if cheatgrass abundance is below a certain invasion state. At that point, continual monitoring of the site is still advised to ensure that appropriate management action will be rapid if cheatgrass becomes too prevalent. Early discovery and recognition of infestations is important because management becomes more challenging as infestation size increases. Assessing the site and selecting appropriate monitoring methods are important steps toward managing a cheatgrass invasion.

Choosing an assessment and monitoring method currently used by a local management agency (e.g., Bureau of Land Management field office) can be beneficial in terms of cooperatively sharing data measured on the same scale and comparing weed invasion trends across similar landscapes. Regardless of the method chosen, the decision is ultimately your own and each method will aid in answering questions regarding clearly defined goals for the property. Vegetation attributes will be determined depending on the questions and goals of interest. Vegetation attributes are characteristics of vegetation that describe how many, how much, or what species are present. For example, if the goal is to decrease both the amount of cheatgrass and bare ground over time, evaluating plant cover is one way of determining if the goal is being reached (cover is the vegetation attribute, Table 3-1). Critically compare the advantages and limitations of each option based on the time and energy you are willing to commit (technical descriptions of each method are included in Appendix A), as well as the specific goals set for your land. The methods below are written in terms of assessing cheatgrass on your land, but they are each useful for evaluating vegetation characteristics in the absence of cheatgrass as well.

Presence/Absence

Evaluation of presence or absence of cheatgrass is a simple semi-quantitative measure of infestation. To accomplish this, the observer must be able to identify cheatgrass and whether or not it exists at certain points across the land being assessed. Little time is required to complete a drive-by or walk-through to record observations or take photographs of these

Table 3-1. Vegetation attributes that can be determined using various monitoring techniques. The "x" indicates that this is the primary attribute that can be collected using the method; the "•" indicates the secondary attribute that can be collected or calculated with the technique.

Method	Frequency	Cover	Density	Structure	Utilization	Composition
Photopoint	•			x (with scale)		•
Landscape Appearance					x	•
SamplePoint	x	x				•
Quadrats			x			•
Belt Transect			x			•
Daubenmire	•	x				•
Point Intercept		x				•

points. This method is best used for small cheatgrass populations, as you will be able to tell if and when a population disappears. Though little experience is required to complete this assessment, it is difficult to recognize trends in cheatgrass population dynamics with only its presence or absence being recorded.

Estimation of Population Size

Another semi-quantitative measure that is often used is an estimation of population size (i.e., the number of individuals in an infestation) within a defined area. Just as the presence and absence method, estimating cheatgrass population size requires that an observer return to certain points on the land to record an estimate of the number of cheatgrass individuals present. Alternatively, the observer could record a class boundary to estimate the number of cheatgrass individuals (e.g., 1–10, 11–100, 101–500, 501–1,000 individuals, and so on). Because these population size estimates can be rough and vary significantly among different observers, only large changes can be monitored with confidence. Having an approximate estimate of your cheatgrass population size does provide an index of cheatgrass population trend at the site, which is beneficial.

Weed Mapping

Weed mapping is a qualitative assessment and monitoring technique. Creating a detailed weed map is important because vegetation varies across the landscape and many land managers are responsible for large areas. Mapping weed distribution will help you develop a clear picture of the degree of cheatgrass distribution and severity across the landscape. This technique can range from relatively simple paper-drawn maps of known presence or absence to complex Geographic Information Systems with measures of cheatgrass and desirable plant cover. The level of complexity of a weed mapping program is determined by the land managers' informational needs, available funding, knowledge of the area, and opportunity to invest their time.

Image-Based Techniques

Image-based assessment and monitoring methods, as their names suggest, use photographs to determine the amount of cheatgrass and other plant species that exist at a site. Over time, a series of collected photographs of the same site can demonstrate general changes in cheatgrass cover and population boundaries. Photopoint and photoplot methods provide qualitative data through repeatedly photographing the same location over time. SamplePoint software uses photographs to provide quantitative cover data, which can be more definitive in identifying trends in cheatgrass abundance (see Section III, Quantitative Techniques, in Appendix A).

A photopoint is a landscape photograph taken from a permanent reference location. These photographs can be used to identify changes in dominant landscape vegetation. The photo location needs to be documented and denoted by a "permanent" reference point in the foreground (e.g., fence post or fence line) along with a distinct "permanent" landmark on the skyline. This ensures that each photograph is taken in the same location, making them useful in comparison.

Photoplots are close-up photographs of a defined area (small plot). Each photograph is taken from above the plot. As opposed to the photopoint method, photoplots result in close-up photographs that show characteristics of the soil surface and the amount of ground covered by vegetation or litter. Typically, a 3-foot square frame is used for plot definition. Each plot location and date of the photograph must be documented to allow for repeated assessment at the same site when the plants are in approximately the same growth stage. This will provide visual evidence of any changes in vegetation or soil. The photopoint and photoplot methods are simple and require little time and equipment. Limitations to these methods, such as difficulties in analyzing and comparing photographs, could make definitive cheatgrass assessment challenging with photographs alone.

Gathering Utilization Data

The landscape appearance method is a commonly used technique to estimate forage utilization. This method is well-suited to situations where grazing or browsing utilization must be estimated over large areas with only a few individuals conducting the evaluation. For the landscape appearance method, an ocular estimate of forage utilization is based on the general appearance of the rangeland or area being evaluated. Utilization levels are determined by comparing observations with utilization class descriptions (see Landscape Appearance Method form in Appendix B). The utilization estimates are evaluated against the standards, goals, or objectives set for the area being evaluated.

This method is often used only on key areas and is especially helpful when the objective is to develop a utilization map of an area. It should be used throughout the grazing unit and can provide the basis for livestock utilization mapping. Proper grazing management promotes the health of the perennial plant community—a vitally important tool for reducing likelihood of cheatgrass dominance. Cheatgrass thrives in areas with bare ground or with limited competition from existing vegetation. Therefore, maintaining proper utilization rates to ensure healthy desirable vegetation is an inexpensive and efficient way to manage cheatgrass.

Conducting the landscape appearance method is rapid and does not require non-grazed areas to train observers. Estimates are made based on a range (class) of utilization rather than an exact amount. Different observers are more likely to estimate utilization in the same class than to estimate the same percentage of utilization. This method, however, can still result in varying estimates with different observers. Another limitation is that there is really no way to assess the accuracy of the estimate due to the data collected being qualitative.

Image-Based Techniques

SamplePoint is another form of image-based assessment that can quantitatively analyze vegetation cover for a defined area. For this method, a 100-foot or 100-meter transect is laid out and 10 photographs are taken at increments along that transect. Photographs are then downloaded into the SamplePoint software (available free at http://www.samplepoint.org/) to be analyzed. Using SamplePoint as a measure for cheatgrass cover has many advantages. First, fieldwork is efficient and SamplePoint is one of the more accurate methods used for measuring canopy cover, partly because it reduces user bias when estimating cover. Also, analyzing photo data with SamplePoint allows for easy generation of summary graphs and produces a permanent electronic record of each transect. This makes future referral to collected data simple. Despite the many benefits of SamplePoint, however, land managers should realize that cover is an inherently difficult measure to make and there is a chance that shadows in the images could hinder vegetation identification, resulting in inaccurate data.

Gathering Density Data

Density is another commonly used assessment method. Calculating the density of cheatgrass and other vegetation on a site involves estimating the number of individuals in a given unit of area (usually referred to as a quadrat). Consequently, density provides a quantifiable and absolute measurement of vegetation in a certain area. We mentioned earlier that defining the unit of measurement is important in data collection. Here, since delineation of separate individual plants can be difficult, density can also mean the number of stems, inflorescences, culm groups, or other parts per unit area. Keys are to determine the unit of measurement early and remain consistent with all observations. For large infestations, this technique should be paired with photopoints or mapping of infestation boundaries to monitor for spread or retraction.

Measuring the density of cheatgrass has definite advantages in addition to providing quantitative data. You can compare cheatgrass density between sites, even when the area of observation differs since it is reported as a per-unit-area measure. Also, since information regarding seedling emergence, survival, and mortality can be determined with multiple density measurements, you can see how sensitive cheatgrass is to changes in climate, resource availability, and implemented management actions. Density may be an important vegetation attribute to consider during restoration projects to determine establishment rates of newly seeded desirable species. Finally, density assessments can be fast and simple depending on characteristics of the area you are sampling.

Since cheatgrass is affected by annual variations in precipitation and canopy cover, density measurements are effective at documenting changes in recruitment or loss of individuals. However, when measuring native perennial bunchgrasses or shrubs, density may not provide useful data on changing plant vigor (i.e., loss of production may not be accompanied by an increase in mortality or decrease in recruitment). Observer error is another limitation of measuring density that can occur when small individuals are overlooked or counts are taken too quickly. Establishing a minimum time per area can help reduce the temptation to hurry while assessing. Though density can be taken within any chosen plot size, there is no single size or shape that will guarantee sample of all species and life forms of interest, often limiting density to a few key species. Larger and denser populations could slow the process of density measurements.

The belt transect method is one of many methods to document density (Appendix A). It is appropriate for early detection of cheatgrass establishment and could aid in detecting cheatgrass coming into an area. Specifically, it can be used to quantitatively monitor the appearance of small seedlings where the cheatgrass is already known to exist in the seed bank or where there is a high risk of introduction. Also, the belt transect method is often used to detect changes in species with low cover or density (generally less than 5-percent cover). The belt transect, in this case, has an advantage over point intercept, which requires higher percentages of species cover in order to be detected.

Gathering Cover Data

Cover assessment methods measure the percentage of ground surface covered by vegetation. We can generally think about cover in two ways. First, basal cover is the area of ground surface covered by the base of a plant. Canopy cover, on the other hand, is the ground surface covered by the plant canopy when looking down on it from above (see Fig. A-4 in Appendix A for visual explanation). For any cover measurement, you can use a transect or assign plots within which to determine what percentage of total cover each species represents. Using either the basal or canopy cover method, consequently, gives a good estimate of biomass by species. In comparison to density measurements, determining cover with plots makes matted or rhizomatous plants easier to account for since you are not required to count individuals, only to estimate a percentage of total cover. Cover also equalizes the role of very small species with species that are large but few in numbers, making community composition estimates more accurate.

When using a cover method, it is challenging to determine whether changes in cover are occurring with density or production because cover measurements are influenced both by shifts in species number (mortality and recruitment) and vigor (biomass production). As a result, trends in cover data may be difficult to interpret. Cover measurements are subject to these changes in biomass throughout the growing season, meaning that land managers will have to conduct cover measurements quickly to be able to compare results across a large area. Due to its time-consuming nature, completing cover measurements rapidly can be challenging.

Two common cover assessments discussed here are Daubenmire and point intercept. The Daubenmire method requires the observer to systematically place a 20x50-centimeter quadrat frame along a permanent transect. By looking down through the frame, you can visually determine what percentage of cover exists in the plot. Total canopy cover and canopy cover by species can be determined with this method. This visual estimation of cover can lead to an unknown level of observer bias; however, the Daubenmire method is generally completed easily and quickly. It is also effective for recording rare species within the plot.

The point intercept method measures cover based on observations made along a transect at specified intervals. At points along the transect, the observer uses a pin to record the number of "hits" (times the pin made contact with the target species) out of the total number of points measured. Point intercept can be used to measure cover for individual species, total cover, and species composition by cover. You can also use it to measure major characteristics of the ground and vegetation. Large areas can be sampled simply with the point intercept method, which allows for collection of large sample sets and easy replication.

In comparison to the Daubenmire cover method, point intercept can overlook rare species, though, as points along the transect seldom intersect with those species. Additionally, measuring a small number of points along the transect can lead to extreme variations in data collected. Due to the nature of setting up transects, tall plants or dense shrub communities can reduce the ability to install a straight-line transect. This can lead observers to avoid certain components of the plant community, adding bias to the data collection.

ORGANIZING AND ANALYZING DATA

After completing a pre-treatment assessment of your land and continuing to monitor, you will have accumulated critical data. The key to making data useful is to understand how to organize and analyze it. Of course, there are countless ways to organize and analyze data. Some managers may use a field notebook to record data and keep it organized by date and year. This method is most useful for qualitative data when non-numeric site descriptions are being compared to each other. For quantitative data, it may be more appropriate to input data into a computer program (such as Microsoft Excel) for analysis. This way, you can easily create simple regression graphs to detect trends in data over time. For example, if you monitor the same site for three consecutive years, you would be able to graph any changes in cheatgrass and other vegetation over that time. If only conducting one assessment, a computer system would still make organization of quantitative data easier to access and refer to. In the end, no matter what data analysis method used, it is most important to create a descriptive story with your data. Use your data to describe trends in cheatgrass, native, and other non-native (both desirable and undesirable) plant populations to track disturbance regimes, or even to describe variation in climatic conditions. Producing a detailed and data-supported story of your landscape is beneficial in many ways. First, it will help you and future managers understand the land, including its history and potential. Second, it makes sharing your experience and your data with others more effective. Communication of results can assist others in evaluating their vegetation communities, and it can foster cooperative relationships between and among landowners, management agencies, and others.

INTERPRETATION AND APPLICATION

Levels of Invasion

You should have a good idea of the level of your cheatgrass infestation after you have completed a pre-treatment assessment. There are a number of ways to measure and interpret the level of infestation, and, to some degree, your management goals will come into play. Once determined, the invasion state is a simple way to define the level of cheatgrass infestation, choose a management strategy, and determine the recovery potential of your land. In this handbook, we use five levels of cheatgrass invasion based on the Cheatgrass Rapid Assessment Protocol (see Appendix A).

When addressing issues such as cheatgrass, it is important to remember that you are managing an ecosystem. Try to look beyond the problem at hand, and work to gain an understanding of the multiple components within the system. For example, understanding native or desirable cover is important for determining whether there is an adequate seed source to promote native plant establishment after cheatgrass is managed or if reseeding is necessary. Understanding the size of a cheatgrass infestation is important for determining methods of control as well as how to prioritize infestations to meet management goals.

The five cheatgrass invasion levels are based on departure from a reference state or goal, thus taking into account both cheatgrass cover and native or desirable cover (Fig. 3-1). One way to think about a reference state is to imagine a state where all the goals you have for your land are met. There may be a physical site that encompasses the vegetative composition and function desired, or you may just have an idea of the state you prefer. Departure from a reference state is the degree to which your site is different from your desired reference state (management target for vegetation). The five invasion states below assume a reference state of undisturbed and highly functioning rangeland as well as a goal of cheatgrass eradication. Although these levels are defined below in terms of multiple components of the system (cheatgrass cover, state of the native community, ecosystem function, intended use), the main purpose is determining the level of cheatgrass invasion.

Invasion State	**Cheatgrass Free** There is no cheatgrass present on the site. Desirable community is thriving; functional and structoral groups are represented.	**Trace** Cheatgrass is present (1-5% cover) but manageable. Desirable community is thriving; functional and structural groups are represented.	**Mild Infestation** Cheatgrass is common (6-25%). Desirable community is still present and functioning.	**Moderate Infestation** Cheatgrass is approaching dominance (26-50%). Desirable community is impacted with some structural and functional groups missing.	**Cheatgrass Dominated** Cheatgrass comprises a majority of the vegetation (51-100%). Desirable community is rare or non-existent.
Level*	Level 1	Level 2	Level 3	Level 4	Level 5

*The levels and corresponding colors are to help guide you through this handbook. Once you determine your current infestation level, look for circles of that color in subsequent sections. This will indicate which information may best apply to your situation.

Figure 3-1. Levels of infestation.

Figure 3-2. Cheatgrass free (Level 1): more than 50-percent perennial grass cover, more than 20-percent litter cover, and very little bare ground.

Figure 3-3. Trace infestation (Level 2): about 4-percent cheatgrass, 35-percent perennial grass, and 15-percent litter.

Figure 3-4. Mild infestation (Level 3): about 20-percent cheatgrass cover and about 50-percent shrub cover. The sagebrush at this site may be at increased risk to wildfire because of the fine fuels in the understory of cheatgrass.

Figure 3-5. Moderate infestation (Level 4): about 30-percent cheatgrass and about 35-percent perennial grasses.

Figure 3-6. Cheatgrass dominated (Level 5) state of invasion: about 80-percent cheatgrass cover while remaining cover is primarily litter.

The first invasion state is **cheatgrass free**. In other words, no cheatgrass is present on the site, and there has most likely been no departure from the reference state. The vegetative composition is all native or desirable introduced species, the ecosystem is highly functioning, and it is probable that the land is functioning appropriately for its intended use. (Fig. 3-2)

The second invasion state is a **trace** infestation. Cheatgrass is present in small amounts, about 1–5-percent cover, so it is still very manageable. The native community is still dominant, and the ecosystem is still functioning appropriately. Recovery potential is very high due to an adequate seed source of desirable species, and management cost and effort should be low with immediate action. (Fig. 3-3)

The third invasion state is a **mild** infestation. Cheatgrass is common (6–25-percent cover), and a desirable community is still present. If you were to manage cheatgrass at this level, recovery potential would still be high, but potentially with higher costs and effort than the previous invasion state. At this point, the functionality of the ecosystem is likely negatively impacted. (Fig. 3-4)

The fourth invasion state is a **moderate** infestation. At this point, cheatgrass is approaching dominance (26–50-percent cover). In this fourth state, the desirable community is impacted, with some or many structural and functional groups missing, resulting in decreased diversity. There is still the potential for recovery, but it has been compromised. The cost and effort for recovery will be significantly higher compared to lesser invasion states. The ecosystem no longer functions as it did before such significant invasion. The ability of the land to function for its intended use may be compromised depending on management goals. For example, there may be decreased soil stability and, consequently, more erosion, or a decrease in plant diversity leading to lower quality forage. At this level, you may be approaching a critical level of invasion, or a threshold. See the sidebar on thresholds for more information on this term and its implications. (Fig. 3-5)

The fifth and final invasion state is **cheatgrass dominant**. Here, cheatgrass comprises a majority, if not all, of the vegetation community (51–100-percent cover). The desirable community is rare or non-existent. Recovery potential is very low, even with very high economic inputs and effort. The ecosystem is no longer functioning properly. Please refer back to the biology section for examples of ecological impacts this fifth invasion state may be having on the ecosystem. Unless there is no intended use, the ability of the land to function properly as intended has probably been impaired moderately to drastically. (Fig. 3-6)

Once again, it is important to stress that the level of impact felt by each of these invasion states is dependent upon the goals and intended use by the land manager. Determining the invasion state and correct management strategy both require a judgment call. (Fig. 3-7)

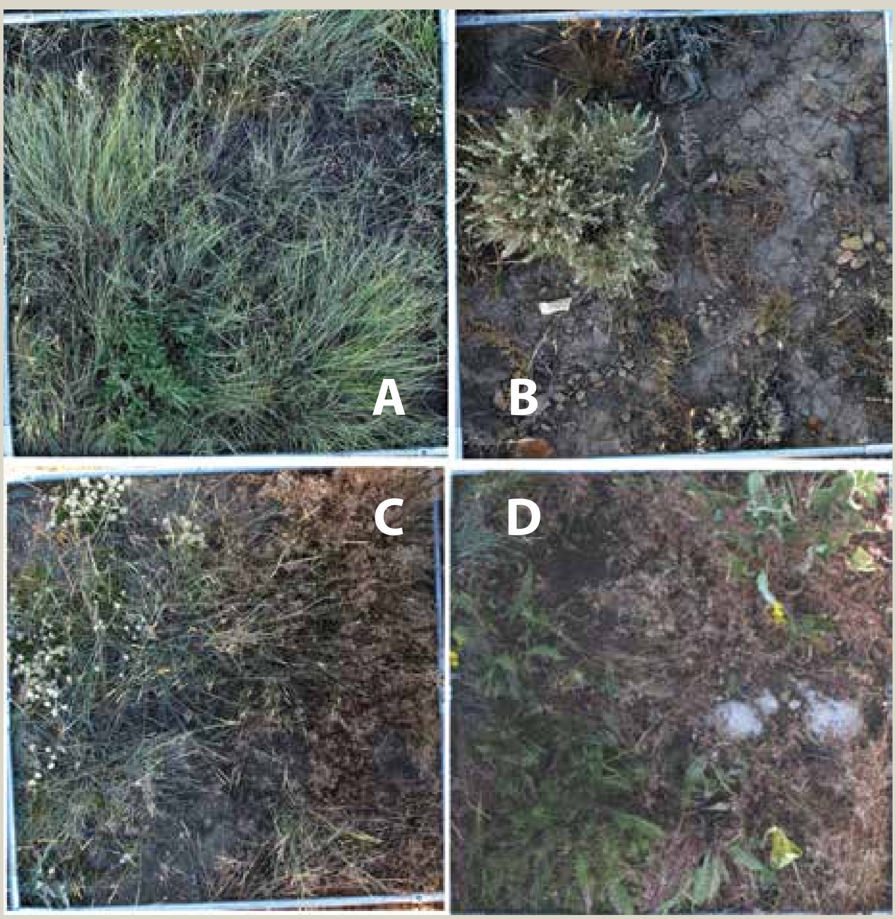
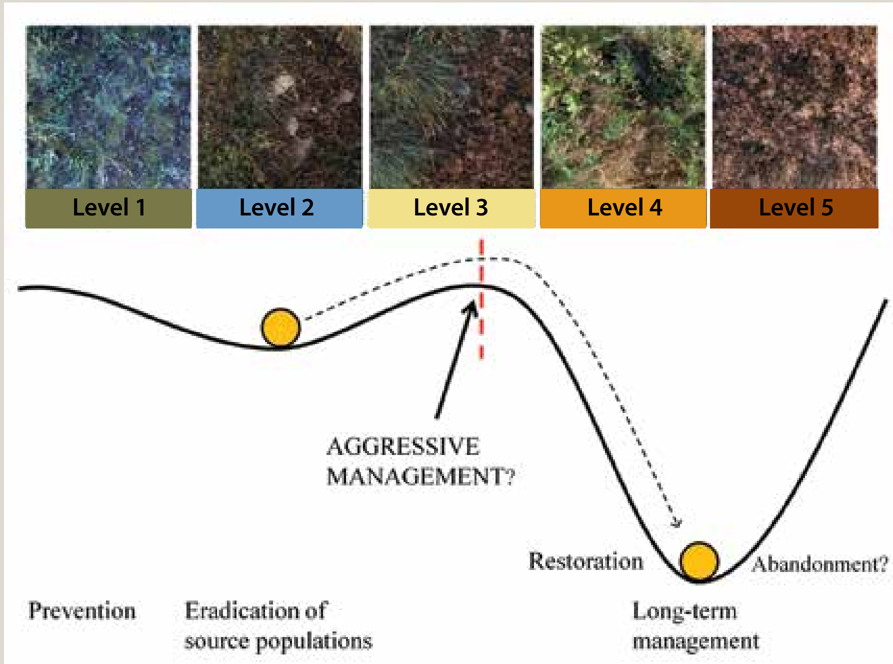


Figure 3-7. A) Cheatgrass free (Level 1): about 50-percent perennial grass cover, about 20-percent litter cover, and very little bare ground; B) Cheatgrass free (Level 1): This site is free of cheatgrass but is largely dominated by bare ground (more than 50 percent). Shrub cover is approximately 20 percent; C) Moderate infestation (Level 4): about 30-percent cheatgrass and about 35-percent perennial grasses; D) Moderate infestation (Level 4): This site has about 35-percent cheatgrass but only 5-percent perennial grass with more forbs (about 35 percent).

SIDEBAR 3-2. THE CONCEPT OF THRESHOLDS: LIFE ON THE EDGE



The concept of ecological thresholds has been defined in various ways by different researchers. Stringham and coauthors[4] define thresholds as the "points in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained equilibrium of the state degrades beyond the point of self-repair." Hobbs[5] simply defines thresholds as "barriers that prevent the recovery of degraded systems." Basically, a threshold can be thought of as a crossover point, a barrier, a transition, or any number of similar concepts at which an ecosystem changes into a new state. The true importance of the definition lies in the implications: once a threshold is crossed and a transition occurs, the land is in a new state. The land can no longer recover alone and does not function as it did before crossing the threshold.

It is easier to think about the concept of threshold in the context of state and transition models because they help us visualize the concepts. The cup-and-ball diagram above is a form of state and transition model where the yellow ball signifies the state of your site. When it is in a cup, it is in a relatively stable state. When it is on a hilltop, the system is unstable. The red dotted line signifies the threshold. Once the threshold is crossed, the yellow ball enters the deeper cup on the right. At this point, the system is degraded or infested beyond the point of self-recovery. In a system infested with cheatgrass, this is a point when inaction allows the invasive to continue dominating the site. It will take a lot of time and effort to move the land from the state of infestation or degradation back to a properly functioning, desired system.

Once understanding the idea of a threshold, it makes sense to prevent your land from crossing one. Within the invasion process, there are two high-leverage opportunities to avoid crossing a threshold with reduced effort. They include 1) prevention of new infestations in areas where cheatgrass does not currently exist and 2) implementing aggressive management where the system approaches an ecological threshold. Classifying areas for prevention necessitates identification of areas that are currently free of cheatgrass. Highly precarious systems, where crossing of an ecological threshold is imminent, may be characterized by high cheatgrass abundance (cover or biomass) with a strong perennial grass or shrub component. For example, an area with a relatively high sagebrush density or cover with abundant cheatgrass in the understory would be classified as approaching a threshold. Such an area may be of high priority for aggressive management to prevent it from crossing a threshold into a cheatgrass-dominated site. If progressing to such a site, it will have a lower recovery potential and require higher costs and effort in a restoration approach. Refer to Chapter 4 for more detailed information regarding management approaches.

The above invasion states are simplified. It is possible that your site is cheatgrass free but 100-percent bare ground, or that your site is at the trace level, but you also have a trace amount of native or desirable vegetation. Regardless of these differences, management strategies will probably be the same. For example, if you have no cheatgrass but 100-percent bare ground, you will want to focus on preventing a cheatgrass invasion while improving the desirable forage base. Whether you have a trace amount of cheatgrass and a trace amount of natives (perhaps because of a large amount of bare soil) or a trace amount of cheatgrass and a large native population, you will probably still want to focus on eradicating the source cheatgrass population while improving native (and perhaps desirable non-native) vegetation. A small population may be manageable with little cost and effort. The main difference in your strategy will be either focusing on prevention of future invasion or re-establishment of a desirable plant community. Either way, it is relevant for your goals and management to include the ecosystem as a whole, not just cheatgrass.

It is important to have at least a general idea of size and continuity (continuous or patchy) of your infestation(s). It is possible that you will find multiple infestations across your managed landscape. Perhaps one infestation is at level two (trace), but it covers a whole pasture, while another infestation is at level five (dominant), but it only has a radius of 20 yards. Having a general idea of the size of an infestation, or the area it covers, is important for determining how to prioritize infestations for management.

PRIORITIZATION

Prioritization is an essential first step in a restoration plan.[3] Once you have an idea of the level of cheatgrass invasion you are dealing with, it is time to develop a strategy. Perhaps you are willing to tolerate the amount of cheatgrass you have because you have experienced no impacts. On the other hand, perhaps you wish to attack your situation aggressively to ensure cheatgrass does not expand and cause major impacts. In either case, it is important to develop a clear strategy before implementing any management actions. As you determine the management actions or control options you wish to pursue, it is worth spending time developing a plan for prioritization.

Prioritization is a way to analyze the situation and ensure that time and resources are going to be distributed in a way that is most effective. Ideally, prioritization should lead to identification of trace or mild invasions, allowing managers to act early to reduce long-term damage and costs due to spread. There are many methods for prioritizing areas for management. One is to look at overlap of valued landscapes. For example, Meinke and coauthors[3] determined high priority areas of sagebrush habitat restoration based on overlap between healthy sagebrush, sage grouse core areas, and presence of cheatgrass. The highest priority areas were those where healthy sagebrush overlapped core areas but were not invaded by cheatgrass. Another approach is to develop a hierarchy where areas infested by cheatgrass are prioritized based on the number of overlapping areas of importance. For example, an infested area where sage grouse habitat, critical mule deer winter range, and valued livestock grazing pasture overlap would be prioritized over a cheatgrass-infested area overlapped by critical winter range alone. Finally, you might compare level of invasion, or departure from a reference state, to recovery potential of the land (Fig. 3-8). Here, prioritization would involve comparing the level of invasion (which is an indication of time and effort) with the potential of the land to fulfill its intended use along with the potential of the cheatgrass infestation to spread into high quality rangeland.

Probability of recovery or restoration	Departure from the reference state		
	None to slight	Moderate	State change occurred
	All functional and structural plant groups are present, but may not be in desired composition.	Some functional or structural plant groups are missing or under represented; invasive species common, but not dominant	Invasive plants dominate; sagebrush or tall grasses are rare; soil stability and hydrologic functioning may be impaired.
High	**No Action.** Maintain status; monitor to prevent changes. Adjust management as necessary.	**Attempt Passive Restoration** if feasible: If unsuccessful, use active restoration.	**Active Restoration.** Potential for successful restoration is high because of deep soils and higher precipitation. Potential for invasive plant control is high.
Medium	**No Action.** Monitor frequently to ensure that management is adjusted before habitat quality is impaired.	**Attempt Passive Restoration** if feasible. If unsuccessful, use active restoration.	**Active Restoration**, but lower priority because of probability of success.
Low	**No Action.** Monitor frequently to ensure that management is adjusted before habitat quality is impaired.	**No Action.**	**Conduct Inventory** and adjust management to fit new site and conditions.

Figure 3-8. A matrix developed by Pyke[7] to prioritize areas for restoring sagebrush. Developing a matrix to compare the level of infestation of an area along with the potential of that same area to function for its intended use could be helpful in determining how to prioritize cheatgrass infestations for management.

One common method for prioritizing cheatgrass infestations—and a good way to visualize prioritization—is the wildfire model (Fig. 3-9). When a wildfire breaks out, it can begin "spotting." This means that flames are blown away from the main fire and ignite a spot fire somewhere else. A common approach used by firefighters is to attack any "spots" before attacking the main fire. If left alone, spot fires have the potential to grow, spread, and become a much larger problem. If they are discovered when they are still small, spots are easy to put out. Once the spot fires are extinguished, the firefighters focus on the main fire, which is likely larger and will require a lot more time and effort to extinguish. You can see how this model applies to cheatgrass. If you have a large, fifth-level infestation, it will require significant time and effort to manage, while small, second-level infestations will be much easier to manage and eradicate with less time and money required. If your plan is to attack cheatgrass, it makes much more sense to handle the level two invasions before they spread and become costly to manage.

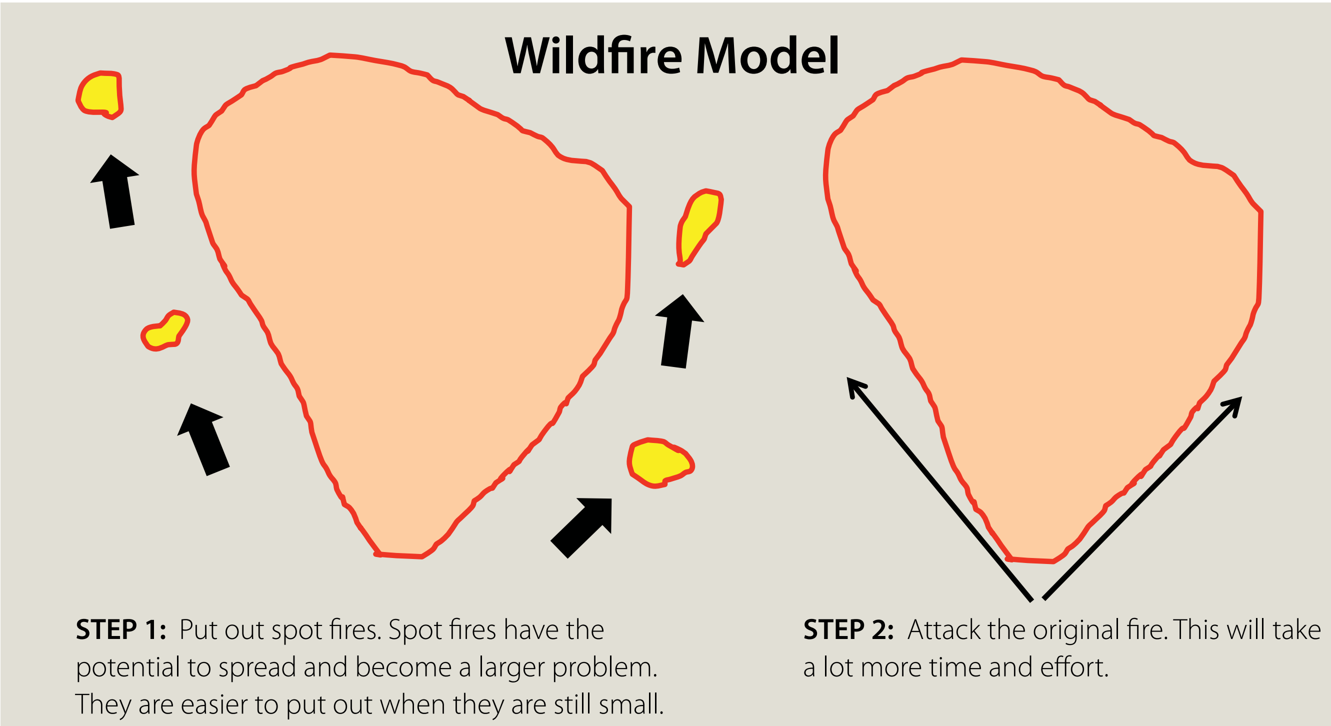


Figure 3-9. The wildfire model depicts a strategy used by firefighters to attack a wildfire. This strategy of prioritizing small, manageable areas first before attacking the larger problem can be applied to the prioritization and management of cheatgrass infestations.

SUSCEPTIBILITY

In a situation where no cheatgrass exists on portions of or all of your land, it is worth considering the susceptibility of those areas to cheatgrass invasion. Table 3-2 demonstrates some high-risk conditions. Although disturbance is a vector of cheatgrass spread, cheatgrass does not require disturbance to establish. Despite the ability to pinpoint a range of elevations where cheatgrass is more probable, there have been instances where cheatgrass has been found at higher elevations than previously thought habitable. Consequently, although Table 3-2 gives some idea of potential troublesome spots to closely monitor, cheatgrass is not necessarily restricted to these areas.

CONCLUSION

In this chapter, we outlined options available for pre- and post-treatment assessment of a cheatgrass infestation. As mentioned above, an assessment gives you a snapshot of your land condition at that point in time. Prioritizing areas of cheatgrass infestations for management ensures that your time and effort is optimized. In the following section, you will be presented with options for treatments of cheatgrass infestations and general management strategies. It is important to remember that the process does not end there. Monitoring is an ongoing practice that allows you to determine if your management actions are effective, if you are meeting goals and objectives, and if the condition of the ecosystem is either trending toward an improved or a more degraded state. The following table includes valuable questions to be revisited throughout the process of managing your land, especially in respect to the treatment of cheatgrass.

Table 3-2. Areas or characteristics of areas with a high susceptibility to cheatgrass invasion.

HIGH RISK OF CHEATGRASS INVASION	
Slope and Aspect	Steep, south-facing slopes
Elevation	2,500–10,000 ft. (http://extension.usu.edu/rangeplants/htm/cheatgrass More subject to microclimate at higher elevation >6,000 ft.[6]
Soils	Shallow[6]
Moisture (temporal)	Dry summer followed by wet fall
Vegetative Cover	Sagebrush-steppe communities
Disturbance (Proximity to/ Overlap with)	Areas burned (recently or sometime in the past) Oil and gas development Pipeline construction Roads Areas formerly farmed Etc.

BOX 3-1. Questions asked throughout the development and continuation of a managment plan.

QUESTIONS FOR POST-TREATMENT VEGETATION MONITORING

Primary questions	Secondary questions
Is the site trending toward my management goals and objectives?	Are there more desirable plants?
Is the treatment working?	Is there less cheatgrass? How long did the treatment last? Do I need to consider re-treating? If so, when?
Do I need to re-prioritize?	
How do I address specific management questions?	How do I collect appropriate data (see Appendix A)?
How will I analyze and interpret information gained from data collected?	

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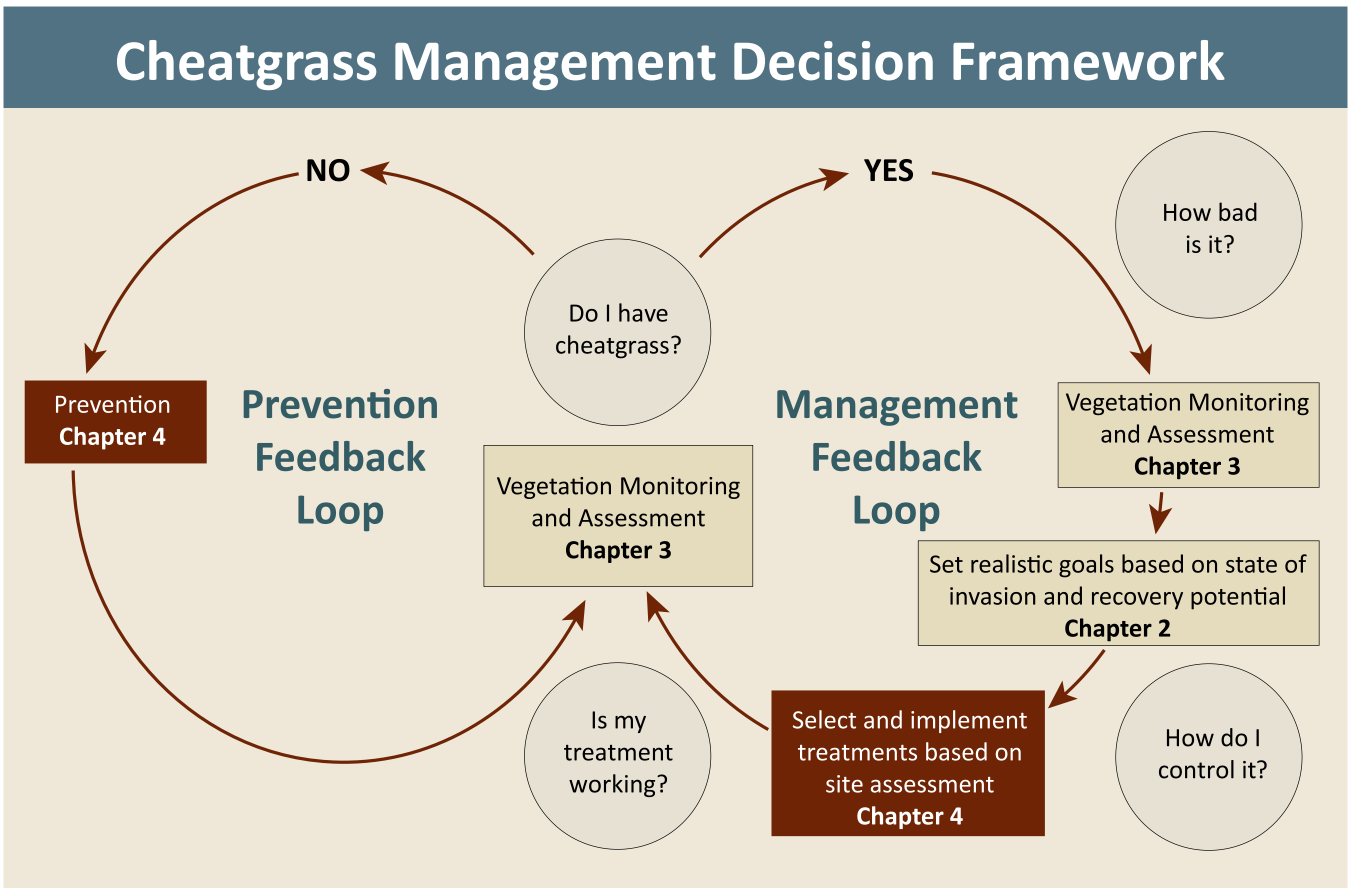
Rachel Mealor

Chapter 4

Management Methods



Chapter 4 – Management Methods

Because of its biology, cheatgrass is largely a war of attrition when it comes to management. Every year that a cheatgrass population produces seed, it replenishes the seed bank for the next population. From a logical standpoint, removing cheatgrass from a system seems simple: completely prevent seed production and the population will not be able to persist into the future; however, there are a few complications with this premise. One hundred percent of each year's seed crop does not germinate every spring, meaning that some seed is dormant, but viable, in future years. Also, it can be difficult to completely prevent seed production in a given year because cheatgrass can re-grow after defoliation, and a population may undergo multiple flushes of germination within the same year if conditions are correct. Given these challenges, a strategic, long-term approach to managing cheatgrass is warranted.

The fact that some seed establishes a persistent seed bank means a long-term commitment to reducing cheatgrass is required. Depending on soil types and precipitation (and on which report you read), the amount of time cheatgrass seeds stay alive in the soil ranges from 3–9 years or more. Cheatgrass can produce a lot of seed. An individual plant, growing free from competition under favorable conditions, can produce 500 seeds or more.[1] High-density stands have been documented to produce more than 70 million seeds per acre.[2] Although such amounts of seed production may not occur often, even a relatively small fraction is capable of leading to a problematic population. Cheatgrass often produces so much seed that plant density is not limited by the amount of seed in the seed bank, but by the amount of spaces where individual cheatgrass plants can germinate and establish.[3]

The characteristics of cheatgrass reproduction and population dynamics lead to a series of interesting mathematical questions. If a manager were to completely prevent seed production (and new seed from entering a site), how many years would it take to fully deplete the seed bank from the soil? If we assume that we are starting with 1 million seeds per acre and were able to completely prevent any new seed from being produced or entering the site, the only additional variable is how much of the seed bank germinates each year. If we make some estimates at annual percentage of germination, then we find that at 99-percent germination, it would take four years, at 95-percent germination it would take five years, at 90-percent germination six years, and at 85-percent germination it would take seven years to completely exhaust all seed from the soil. The numbers demonstrate several important concepts: 1) If managers can prevent seed production—and immigration—for multiple years, then cheatgrass may be removed from the management area; and 2) we may need better information on the viability of cheatgrass seeds in the soil over the long term. Effective management tactics exist (Fig. 4-1), and strategically deploying those tactics across the landscape increases your probability of success.

Figure 4-1. Controlling cheatgrass in a grass-dominated system is possible. Our management approach should allow us to move a system with a high amount of cheatgrass (left and background) toward a system with no, or relatively low, cheatgrass (right foreground) such as seen in this photo. Herbicide was applied within the grazing exclosure the fall prior to this image being taken in the summer. Cheatgrass was suppressing the growth of western wheatgrass, and western wheatgrass was released from competition where herbicide was applied.

MANAGEMENT APPROACHES

Because cheatgrass infestations vary in intensity and impact across the landscape, matching a management approach to the level of infestation should increase efficiency and effectiveness of a management program (Fig. 4-2). As discussed previously, an important step in devising a landscape-scale strategy is prioritizing sites in terms of level of invasion and recovery potential. In this section, we briefly discuss how different management approaches may be suited for each level of invasion.

Prevention – Cheatgrass Free

If you do not yet have cheatgrass on your property, it is worth making a sustained effort to avoid getting it. There are several critical steps to preventing cheatgrass invasion.

1. Keep Seeds Out

The first step to preventing infestations of cheatgrass is to avoid the introduction of new seeds. Below are some of the ways to keep cheatgrass seed off your land or away from cheatgrass-free areas.

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Invasion State</td><td>Cheatgrass Free
There is no cheatgrass present on the site. Desirable community is thriving; functional and structoral groups are represented.</td><td>Trace
Cheatgrass is present (1-5% cover) but manageable. Desirable community is thriving; functional and structural groups are represented.</td><td>Mild Infestation
Cheatgrass is common (6-25%). Desirable community is still present and functioning.</td><td>Moderate Infestation
Cheatgrass is approaching dominance (26-50%). Desirable community is impacted with some structural and functional groups missing.</td><td>Cheatgrass Dominated
Cheatgrass comprises a majority of the vegetation (51-100%). Desirable community is rare or non-existent.</td></tr>
<tr><td>Level*</td><td>Level 1</td><td>Level 2</td><td>Level 3</td><td>Level 4</td><td>Level 5</td></tr>
<tr><td colspan="6">*The levels and corresponding colors are to help guide you through this handbook. Once you determine your current infestation level, look for circles of that color in subsequent sections. This will indicate which information may best apply to your situation.</td></tr>
<tr><td rowspan="7">Potential Management Actions**</td><td>Prevention</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Maintenance</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Eradication</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Aggressive Management</td></tr>
<tr><td></td><td></td><td colspan="3">Long-Term Management</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Restoration</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Abandonment</td></tr>
<tr><td colspan="6">**These are only potential actions. The bar for each action spans the levels with which they may apply. However, the management strategy you choose for dealing with your current level or levels of infestation will depend highly on your overall goals. You have the final decision.</td></tr>
</table>

Figure 4-2. State of invasion relates directly to management strategy. In areas where cheatgrass is absent, continued monitoring for invasion and prevention tactics should be implemented. On a site where cheatgrass has had relatively little impact on the native plant community, recovery potential is likely high and effort needed for successful control may be low. If low-density patches occur over a small area, then eradication of such source populations may be a realistic goal. Cheatgrass may reach a level where management goals are being affected (such as a reduction in forage production). Once cheatgrass effects surpass an acceptable level, the incentive to implement control actions increases. When cheatgrass reaches sufficient abundance to alter the way the system functions (reduced diversity, reduced perennial forage production, increased fire frequency), ecologists may assume that the system has crossed an ecological threshold. At this point, recovery potential may decrease because desirable components of the system may have been lost. Additional investments of time, energy and money may be needed at this stage compared to earlier and less severe stages of invasion. The intentional reintroduction of desirable species through seeding may be needed (restoration). Although it is not a desirable alternative, abandonment of land too impacted by cheatgrass to remain productive may be an option for some managers. **What state of invasion is your site in, and how would you describe your management strategy?**

Buy clean seed

Be sure that any seed purchased for revegetation or pasture planting is not contaminated with cheatgrass seeds.

Keep equipment clean

Attachment of seeds and plants to vehicles and equipment can be an efficient delivery system for many unwanted species, not just cheatgrass.

Buy weed-free hay

Hay can also be contaminated with seeds of cheatgrass. Buying weed-free hay helps to avoid inadvertently introducing cheatgrass contaminants. Unfortunately, cheatgrass is not listed as a prohibited weed as part of Wyoming or Colorado's weed-free forage programs. Thus, purchasing certified weed-free hay might not ensure the absence of cheatgrass seed. Discussing the possibility of cheatgrass seeds with the hay producer will inform you of the potential for introductions.

Avoid spread of seed through animal manure

Some cheatgrass seeds can survive the digestive tracts of livestock. If livestock have been grazing on land infested with seed-bearing cheatgrass, you must ensure that they do not eat cheatgrass for about a week before moving them to areas that are not yet infested. This wait period will allow most of the ingested seed to pass through the animal before it is moved to the cheatgrass-free area.[4, 5] Even if some seed passes from the animals after a few days, the longer the seed has been in the digestive system, the less likely it is to be viable when excreted.[4, 5]

Work closely with neighbors

Cheatgrass and other invasive weeds are landscape-scale management challenges. Because weeds do not respect geopolitical boundaries, a group of landowners working together may be able to increase the likelihood of successful cheatgrass control over a larger area. An individual landowner who implements an excellent cheatgrass management program but is surrounded by infestations that continually serve as a seed source onto his or her property will have a difficult time controlling cheatgrass over the long-term.

2. Make the Environment Inhospitable

If cheatgrass seeds are introduced, it may be possible to prevent plants from becoming established by making the environment inhospitable for the germination of seeds and the growth of seedlings and established plants.

Maintain Cover of Vegetation

Maintaining a healthy cover of desirable vegetation can make it difficult for cheatgrass seedlings to establish. Cheatgrass is not a good competitor with established, perennial vegetation.[6, 7] Thus, maintaining perennials can suppress cheatgrass growth, especially at the seedling stage. This is a good reason to avoid overgrazing your perennial plants. If continuously overgrazed, perennial plants cannot compete with cheatgrass.

Perennial grasses and other plants can benefit from receiving moisture during the middle and late growing season after cheatgrass has completed its life cycle. If you have access to irrigation, you can boost the desired species growth by irrigating when cheatgrass cannot benefit as much as desired perennial grasses.

Minimize Nitrogen Availability in Soil

Minimizing the nitrogen available for plant uptake can help limit cheatgrass growth more than most native perennial species can alone. This is because cheatgrass is a fast-growing, nitrogen-loving species while native perennials are generally slower growing and better adapted to low-fertility conditions. Availability of nitrogen is increased after disturbances since plants die and are no longer taking up nitrogen. If green plants are killed and left on the site, nitrogen held in their tissues will also be returned to the soil through decay and biochemical processes, increasing nitrogen available to cheatgrass and other plants. Soil nitrogen availability goes down if plant materials low in nitrogen and high in carbon are added to the soil. The reduction in available nitrogen may make the environment less suitable for cheatgrass and favor native perennial species (see Nitrogen Management section).

3. Organize a Weed Prevention and Management Area

Even if you are successful at managing and preventing the spread of the cheatgrass invasion on your land, you still risk infestations moving in from neighboring properties. Developing a "weed prevention and management area" with neighbors can help prevent cheatgrass from becoming established in new areas. These areas have been established successfully across the West (e.g., Crooked River Weed Management Area in Montana), and there is information available to help you establish your own. See Box 4-1 for more detailed information.

Aggressive management for local eradication – Trace, Mild Infestation

Eradication is the complete elimination of living plants, plant parts, and seeds of the target weed from a site. Is eradication a viable goal when discussing cheatgrass? The answer depends on the spatial scale of the management area and the level of cheatgrass infestation. The probability of eradicating cheatgrass from the entire state of Wyoming, even from all of Natrona County, for example, is remote. However, the eradication of low-level cheatgrass invasions from a single pasture, ranch, or other property is more realistic.

If your goal is complete eradication, several management actions should be considered. Since cheatgrass is an annual plant, preventing seed production each year should deplete the seed bank over time. Any management tactics that reduce seed production and reduce the probability of cheatgrass population growth should also be implemented. Any control actions that reduce the health and vigor of the desirable plant community on-site are not recommended. A healthy and vigorous desirable plant community may provide the best long-term solution for reducing cheatgrass spread and impacts.

BOX 4-1: CREATING A WEED PREVENTION AND MANAGEMENT AREA

Starting a Weed Prevention Area

A weed prevention area (WPA) is an association of land owners and managers in a particular area, such as a watershed or county, that works together to help prevent the spread of cheatgrass and/or other invasive plants into areas that have not yet been infested. Prevention activities are those carried out before eradication becomes infeasible. This includes implementing the weed prevention steps described in the Prevention section, monitoring to detect new occurrences, eliminating the first individuals to appear, and launching educational activities to raise public awareness about the problems associated with cheatgrass and other undesirable plants and also stopping weed spread. WPAs can be organized and managed like a cooperative weed management area (CWMA), but the purpose is to prevent weed spread into un-invaded areas and eradicate satellite populations on otherwise weed-free land. You can establish a WPA by taking the following steps:

- Propose the WPA to land owners and managers in the area, identify someone to lead it, and build support from people in the community.
- Establish the WPA by holding a meeting(s) of relevant stakeholders, setting up the governance structure, and identifying its boundaries.
- Develop a plan of action.
- Carry out the plan.
- Evaluate the results, and revise the plan accordingly.
- Revise the plan to fill in gaps in planning or execution that allowed cheatgrass or other target species to spread into new areas.

This information was adapted from the USDA–ARS' EBIPM handbook ***Establishing a Weed Prevention Area: A step-by-step user's guide***.[40, 41] Consult this guide for more details; to find it, simply google the name.

Aggressive management to prevent loss of desirable habitat characteristics – Mild infestation, Moderate Infestation, Cheatgrass Dominated

Aside from local eradication, aggressive management may also be necessary when a vegetative community is approaching an ecological threshold (Fig. 4-2). The concept of ecological thresholds has been understood for decades,[8-10] but scientists are still determining how to identify thresholds in the field.[11] Thresholds, as discussed in Chapter 3, represent an ecological barrier that, when passed, pushes an ecosystem into a new steady state. Once in that new state, the ecosystem requires considerable management to return to its original form. When managing cheatgrass, there are certain indicators that a major shift (threshold) in vegetation is imminent. For example, a site with abundant cheatgrass in the understory of a big sagebrush stand may be at risk for a wildfire. Big sagebrush expansion is limited by fire while cheatgrass expansion is facilitated by it (see Prescribed Fire section). Once burned, it could take many years for sagebrush to recover to the pre-burn state. In the meantime, cheatgrass populations could increase at the site, limiting sagebrush reestablishment. In this case, fire pushed this big sagebrush system with a cheatgrass understory over an ecological threshold. Consequently, management of such a system should be implemented before the large reduction in sagebrush by a cheatgrass-driven wildfire. Such aggressive management actions could prevent the loss of desirable vegetative characteristics while controlling cheatgrass. These general strategies could prevent a site from crossing over an ecological threshold.

Long-term management to reduce economic and ecological impacts of cheatgrass and reduce cheatgrass invasion to a more acceptable level – Mild infestation, Moderate Infestation, Cheatgrass Dominated

Sometimes it is not practical to try to aggressively reduce the cheatgrass population but rather to reduce it below some level where it does not significantly interfere with management objectives. These management strategies do not seek to fully remove cheatgrass from the site. This approach may be appropriate when the cheatgrass infestation is moderate or dominant across a large management unit. Although cheatgrass is one of the most widespread problematic weeds in the West, the effort required in managing it needs to be weighed against the potential benefits of control. For example, some land managers may perceive that there is an economic benefit in keeping cheatgrass because it provides early spring forage. Other landowners may determine that cheatgrass is so extensive it is reducing their overall forage availability when compared to pasture productivity prior to cheatgrass invasion. In this case, the cost of controlling cheatgrass may be worth the economic gain from increased forage production of perennial grasses. Grazing should be managed to minimize an increase in the cheatgrass population and to ensure continued health of desirable vegetation.

Even if you choose to implement a management plan that does not intend to eradicate cheatgrass, it is still important to diligently monitor vegetation. Monitoring helps identify trends in vegetation that indicate whether cheatgrass is increasing, decreasing, and/or causing impacts on desirable vegetation.

Restoration – Moderate Infestation, Cheatgrass Dominated

Here, we consider any management strategy that requires active human reintroduction (via seeding, transplants, etc.) of desirable plants to be a restoration strategy. A restoration strategy may be required on a site that is dominated by cheatgrass or devoid of desirable vegetation. Typically, a site that is at a lower stage of invasion will still have enough desirable plants to respond favorably to cheatgrass reduction.

If we are not familiar with the history of a site, it is difficult to determine 1) if desirable plants are lacking because of cheatgrass, or 2) if cheatgrass is abundant on the site because few desirable plants existed at the time of cheatgrass introduction. In either case, a site with depleted diversity and productivity of desirable plants may be in need of restoration. Similarly, a site that has crossed this ecological threshold would also be in need of restoration. Like other strategies, a restoration approach requires a long-term commitment by the land manager. Expenses may increase significantly when implementing restoration of a site. Native plant seed can be costly, necessitating that the decision to restore a cheatgrass-dominated site be carefully considered.

SELECTING A CONTROL METHOD

Selection of the appropriate tool(s) depends on site characteristics, state of invasion, and goals for the site. There are several control methods documented to impact cheatgrass populations. Whichever method(s) is selected should be in accordance with land-management goals and personal management preferences—and, preferably, with close collaboration with neighbors and perhaps others. It would be ideal if this handbook could recommend the single best method for controlling cheatgrass in every situation, but there is no one "silver bullet" that will work for managing all types of cheatgrass challenges. Many of the control methods have been documented as successful in different situations, but implementing the selected control method within the management process should enhance chances of meeting vegetation goals.

In this section, we provide general information on multiple management tactics that may fit into your cheatgrass management program. Some methods may not be necessary in certain states of invasion (see Chapter 3), while some situations may call for the integration of multiple methods of control. A pre-treatment vegetation assessment can provide valuable information for selecting suitable management methods.

Prescribed fire

The relationship between cheatgrass and fire has been widely discussed in the literature. It is often generalized that fire leads to cheatgrass dominance. In many cases, cheatgrass invasion and dominance are facilitated by fire. Cheatgrass itself may increase the frequency of wildfires in some ecosystems because of its ability to produce high amounts of fine fuels that dry out early in the growing season.[12, 13] If we make the assumption that fire increases cheatgrass, then why would we consider using prescribed fire as a tool for reducing it?

It may be inappropriate to make broad generalizations on how fire affects the desirable plant community and cheatgrass populations across locations and across time. In areas where

SIDEBAR 4-1: THE CONSEQUENCES OF FIRE

Steve Dewey, Utah State University, Bugwood.org

Sagebrush and Fire:
Most sagebrush species occurring in the Rocky Mountain region are not capable of re-sprouting from root crowns following fire. One exception to this is the silver sagebrush species generally more prevalent at the intersection of the foothills' rangelands and the plains to the east. In most cases, sagebrush must reestablish from seed following fire. Sagebrush establishment from seed only occurs during years with prolonged cool and wet springs. Once established, sagebrush seedlings grow slowly. In a highly competitive environment, such as an area with high cheatgrass density, sagebrush seedlings are at a competitive disadvantage and may not survive. More reduced survival rates occur if fire moves through the area frequently, forcing sagebrush to repeatedly establish from seed.

Cheatgrass and Fire:
As an annual plant, cheatgrass reproduces from seed alone and cannot rely on a perennial root system for year-to-year revegetation. Cheatgrass seeds germinate and grow rapidly when temperature and moisture conditions are conducive (see Chapter 1). They are also capable of effectively using resources made available when plant material is broken down by fire. This competitive resource acquisition strategy of growth and reproduction favors cheatgrass over plants with slower establishment and growth characteristics, such as sagebrush.

conservation of sagebrush habitat is not a concern, prescribed fire alone or integrated with other control methods[14, 15] may play a role in reducing cheatgrass abundance. Well-timed prescribed fire has been reported to kill cheatgrass seedlings (T. D'Amato personal communication; C.S. Brown personal observation). These management burns are conducted in spring when there is sufficient standing dead biomass to carry the fire. Having the necessary legal permits in hand, making sure all environmental conditions are conducive for such a burn (i.e., moisture in plant material, temperature, wind, and humidity), and ensuring that trained personnel and proper equipment are available at the ideal stage of cheatgrass development are among the requirements. Thus, this approach may rarely be an option.

Flames may be able to directly consume up to 98 percent of a current year's cheatgrass seed,[16] but the abundance of cheatgrass seeds in the seed bank before the fire directly relates to the amount of cheatgrass that might be expected post-fire.[17] Prescribed fires usually reduce plant litter accumulated at the soil surface. Since cheatgrass germination and establishment can be facilitated by litter,[18, 19] reduction in litter may lead to increased desiccation of cheatgrass seedlings and a lower survival rate. Thick litter layers have been anecdotally related to diminished herbicide efficacy, so a reduction in litter may also increase the amount of herbicide reaching the soil surface or the leaves of young seedlings, where it must be for a herbicide application to be successful.

Because of the potential to increase cheatgrass on a site, using fire as a management tool should be done with a high degree of caution. Without integrating herbicides, revegetation, and proper grazing management, the use of fire alone may provide uncertain or undesirable results.

Targeted grazing

Cheatgrass itself can provide valuable, early-spring forage for livestock.[20, 21] Thus, grazing as a biological control method seems to provide the opportunity to achieve a reduction in cheatgrass populations while adding weight to livestock. Removal of aboveground growth by grazing is not likely to prevent seed production in a population entirely.

How much aboveground biomass reduction might we expect with grazing? An Oregon study demonstrated that a twice-repeated defoliation (clipping) event in the early boot stage reduced cheatgrass seed production by more than 90 percent.[22] This reduction is significant, but such results still leave hundreds or thousands of seeds per square meter of soil—enough to maintain a healthy cheatgrass population. A Nevada case study suggests that two years of intense fall grazing (>80-percent utilization of newly emerged cheatgrass) may moderately reduce cheatgrass cover,[23] but more information is needed to determine if this observation is repeatable. Another Nevada study indicated that two years of targeted early spring grazing followed by fall prescribed fire decreased cheatgrass cover significantly while increasing cover of Sandberg bluegrass (a cool-season perennial bunchgrass). However, there was also a significant increase in cover of undesirable annual mustards. Targeted spring grazing alone did reduce cheatgrass cover but without the accompanying increase in Sandberg bluegrass.[15] In several clipping studies, cheatgrass plants still produced seeds after being clipped. In those cases, the amount of seed produced was largely dependent on moisture availability that facilitated re-growth.[22]

Grazing alone can potentially reduce the abundance of cheatgrass in a given area. Applying the right amount of grazing pressure at the correct time over the repeated years needed for cheatgrass reduction while minimizing negative impacts on desirable grasses may be difficult. This is especially true when repeated early-spring grazing can be detrimental to cool-season perennial grass species. Because of this, more long-term information is needed on the use of grazing as a tool to manage cheatgrass on a landscape scale. For more detailed information on the use of grazing as a tool to manage cheatgrass and other weeds, refer to the *Targeted Grazing* and the *Grazing Guidelines* handbooks—along with other information—published by the University of Idaho Rangeland Center, the American Sheep Industry Association, and others (http://www.webpages.uidaho.edu/rx-grazing/index.htm). Also see the USDA–Agricultural Research Service (ARS) publication *Grazing Invasive Annual Grasses: The Green and Brown Guide* (http://sfc.smallfarmcentral.com/dynamic_content/uploadfiles/152/green%20and%20brown%20grazing%20guide-sm.pdf).

Other biological controls

Biological control methods often take advantage of insect herbivores or pathogens from a weed's native range to inflict damage on the target weed population. Research and development efforts on bacteria and fungi are ongoing, but using such methods are currently not available for management-scale treatments against cheatgrass. The two most widely known organisms currently under development are a fungus (*Pyrenophora semeniperda*) and a rhizobacterium (*Pseudomonas fluorescens* D7).[24-28]

P. semeniperda, also known as the "black fingers of death," naturally occurs in the soil and infests cheatgrass seeds.[29] It is capable of reducing the number of viable seeds in the cheatgrass seed bank and has a greater impact on slow-germinating seeds (seeds that may lie dormant in the soil) than it does on seeds that germinate more quickly.[30]

P. fluorescens reduces the growth and vigor of cheatgrass by producing a naturally occurring toxin that attacks the roots.[31, 32] This rhizobacterium is fairly specific to cheatgrass, meaning it has a limited impact on other species.[27] Its most active period of growth occurs at relatively cool soil temperatures, when the growth of cheatgrass may not overlap significantly with other species. This may serve as one potential mechanism for its selectivity. Research is ongoing regarding these two potential biological control agents for managing cheatgrass, and they, among others, may be valuable tools in the future.

Nitrogen management

Research indicates that the ability of cheatgrass to invade and become dominant on some sites is related to its ability to use available nitrogen more efficiently than slower-growing native plants.[33-35] If cheatgrass invasion is facilitated by available nitrogen, then a management action that reduces nitrogen availability should potentially reduce the competitive advantage of cheatgrass. High-carbon, low-nitrogen materials (i.e., sucrose, wheat straw, sugarbeet pulp, sawdust, wood chips, activated charcoal, and others[33, 36]) can reduce nitrogen availability. These materials reduce nitrogen because they provide food for microbes, which absorb available nitrogen as they break down the high-carbon substances. When such high-carbon materials are placed on, or incorporated into, the soil,[37, 38] microbes get busy eating, growing, and reproducing. Instead of being readily available for plant uptake, the nitrogen becomes part of the microbes themselves.

Carbon sources will be depleted over time as organic matter is consumed. When that happens, more microbes die than are born, and their decaying bodies result in higher nitrogen availability once again. Some carbon sources take longer for microbes to break down than others. Materials like wood chips and straw take a long time to decay, while the microbes consume sugar within days to weeks (depending on how much is added). When the excess carbon is gone and nitrogen availability increases, higher nitrogen becomes available for desirable plants as well as for cheatgrass. Thus, addition of high-carbon materials creates only a small window of opportunity when nitrogen levels are low. Here are a few concepts to consider when using high-carbon materials to reduce nitrogen availability:

- What high-carbon materials are you going to use?
- Are they readily available, and how much will it cost to add sufficient amounts to reduce nitrogen availability?

- How often must more material be added to keep nitrogen levels low?
- Is there a critical period for establishment and/or growth of desired species during which suppression of cheatgrass is most important? Perhaps addition of high-carbon materials can be used during this important time so reapplication will not be necessary.

As with many of the other control methods, soil nutrient management is still under study. Short-term (about one year after application) studies indicate that carbon addition may reduce cheatgrass populations with little effect on desirable grasses. We are aware of no long-term studies documenting the effectiveness of carbon addition for controlling cheatgrass. Carbon-addition rates would ideally be calculated using soil tests of the site to be treated, but rates from 200–900 pounds of sucrose (sugar) per year have been documented to reduce cheatgrass. As with all other methods of control, financial costs (labor, equipment, fuel, materials, etc.) should be taken into consideration. The practical utility of this approach is still under consideration, but it may be an option in localized areas where cheatgrass may become a problem (such as small oil and gas reclamation sites).

Chemical control

Chemical control, or the use of herbicides, is the most widely used weed control method in pastures and rangelands. Chemical control has many advantages for cheatgrass management in natural systems. These advantages include lack of soil disturbance, requiring a relatively low amount of effort, and extensive flexibility in the choice of management system implemented. Some potential problems associated with chemical control may include injury of non-target plants, chemical residues in soil and/or water, and public concerns for human safety (along with the costs to purchase and apply herbicides). Receiving adequate training in the selection, handling, and application of herbicides can minimize such problems. Information regarding such training is available at your local Extension office, including those of Colorado State University (CSU) and the University of Wyoming (UW). More information about the UW Extension program is at http://ces.uwyo.edu/UWPMC.asp. State departments of agriculture and weed and pest control districts also provide valuable information in proper procedures of herbicide use.

Several different herbicides are currently labeled for cheatgrass management in range and pasture or for rangeland restoration projects (Table 4-1). As discussed in Chapter 1, cheatgrass is typically considered a winter annual grass. This means that cheatgrass germinates in the fall when sufficient moisture is received, overwinters as a small plant, and is ready to grow early the next spring. If fall precipitation is not adequate to induce germination and emergence of cheatgrass, it can germinate in the spring of the year as well. As a result of its winter annual growth habit and the potential for multiple germination events within a year, the timing of herbicide application is critical when targeting cheatgrass (Fig. 4-3).

There are several important considerations when using herbicides to manage cheatgrass:

- ***Calibration of application equipment:*** Properly calibrated sprayers help ensure that the correct amount of herbicide is applied to the target areas. Given that many of the herbicides used for cheatgrass control are applied in very small quantities, improper calibration may lead to failed applications (they might not kill cheatgrass, or they might

Table 4-1. Herbicides labeled for cheatgrass control or restoration in rangeland and pasture settings. Always read and adhere to the entire herbicide label and supplementary labeling.

Chemical	Trade name(s)	Application Rates+ (oz. product/acre)	Timing
Glyphosate	Roundup/others	12–16	Spring, prior to seed production
Imazapic	Plateau, Panoramic	4–8	Fall, prior to cheatgrass emergence, or spring before cheatgrass reaches 2″ tall
Glyphosate + Imazapic	Journey	12–16	Fall, following cheatgrass emergence or early spring
Rimsulfuron	Matrix	2–3	Fall, prior to cheatgrass emergence or spring, prior to seed production
Propoxycarbazone sodium	Canter R+P	0.9–1.2	Fall or spring early post-emergence
Sulfometuron + Chlor-sulfuron	Landmark XP	0.75–1.5	Fall, prior to cheatgrass emergence or spring, before plants are 3″ tall
Sulfosulfuron	Outrider	0.75–1.33	Fall or spring early post-emergence prior to three-leaf stage
Paraquat*	Gramoxone Extra	20–24	Late spring (after 90-percent node formation, before full bloom)

* Restricted-use herbicide

\+ Application rate varies according to timing, site conditions, and goals

kill everything, including desirable plants), waste of time and money, and possible environmental damage. If a commercial applicator is hired to work on a cheatgrass project, ask the person about his or her application equipment and calibration. For more information on calibrating sprayers, see the TechLine News guide at http://www.mtweed.org/library/wp-content/uploads/2010/08/calibration-techline-2012.pdf.

- ***Use herbicides only when necessary:*** Chemical control works well in many situations, but it is not the only solution to manage cheatgrass. Make sure the use of herbicides is warranted, safe, and economically feasible for your situation.

- ***Always follow label instructions and restrictions:*** Herbicide labels are legally binding documents. Read and fully understand the safety precautions, environmental and grazing restrictions, and use information provided on the label before working with herbicides.

- ***Reduce probability of herbicide-resistant weeds:*** Although herbicide-resistant weeds are more prevalent in croplands, the potential for an annual weed, like cheatgrass, to develop resistance still exists. Herbicide-resistant weed populations have the ability to survive and reproduce after herbicide treatment with a dose that would normally be lethal. Resistant populations develop in response to natural selection pressures associated with repeated herbicide applications. The potential of developing a resistant population can be minimized by using different herbicide modes of action (how a herbicide works within a plant) and by using methods of control other than herbicides alone. Each of the herbicide "profiles" below includes a mode of action group number (i.e., groups 2, 9, and 22). Herbicides from the different groups work differently within the

Figure 4-3. Why timing of application is important. The timing of a treatment application is always important, regardless of the method. This photo shows five individual cheatgrass plants collected on the same day in October 2012 from a one-square-foot area. Many herbicide labels suggest application for optimal control when cheatgrass is at the 1–3- or 2–5-leaf stage, and that control is reduced when cheatgrass persists beyond those growth stages. Based on the photo, it seems that we may control individuals within the population that were smaller at the time of application while having little impact on the larger members of the population. Livestock grazing cheatgrass in the spring may face a population with some individuals that are palatable and others that have begun to set seed, thereby reducing their palatability. Such variation in growth stages within a cheatgrass population may create management challenges when a narrow application window is required.

biochemical pathways of the plant. If repeated applications of herbicide will be used on a given area, consider using herbicides from different groups through time to help prevent the development of a resistant population.

Selected herbicides for cheatgrass management

Glyphosate (Roundup®, Rodeo®, Glyphomax®, Accord®, and others)

Glyphosate is sold under different trade names and multiple formulations. Thus, be sure to read the label of each individual product carefully. This herbicide inhibits the synthesis of proteins (Group 9). It is registered for use in many different systems including rangeland, pasture, crop, and non-crop areas. Glyphosate is nonselective, meaning it can potentially kill most plants. Selectivity of glyphosate can be increased by timing and rate of application. Application at a rate of 12–16 fluid ounces per acre applied to cheatgrass that is less than 4 inches tall can provide good to excellent control. However, non-target species actively growing at the same time are also likely to be damaged—or even killed. Applications when cheatgrass is actively growing and desirable plants are dormant is ideal when using glyphosate in a cheatgrass-management program.

- Rate: 12–16 fluid ounces of product per acre (Roundup)
- Timing: When cheatgrass is actively growing and non-target plants are dormant, unless some injury to desirable plants is acceptable
- Restoration considerations: Glyphosate has no residual activity in the soil, so it may provide a good option when seeding of desirable plants is needed.

Imazapic (Plateau®, Panoramic®)

Imazapic is an imidazolinone (Group 2) herbicide registered for use on rangelands, pastures, natural areas, and other non-crop areas. Imazapic is anecdotally known as being the most widely used herbicide for cheatgrass control in rangeland settings. The herbicide works by preventing the synthesis of several amino acids, which stops protein synthesis. It can impact many different plant species when applied at high rates during susceptible stages of growth. It is most effective for cheatgrass control when applied prior to cheatgrass emergence or before cheatgrass grows past the three- to four-leaf stage. Once cheatgrass exceeds this size, desired control is less probable.

- Rate: 2–12 ounces product per acre (target 4–8 ounces)
- Timing:
  - Fall prior to cheatgrass emergence or during early post-emergent stages
  - Spring before cheatgrass reaches 2 inches in height
  - Post-emergent applications require quality surfactant or methylated seed oil (this may increase potential for non-target damage)
- Restoration considerations: grasses reported on the label to be tolerant of different rates of imazapic:
  - Newly seeded grasses:
    - (2–12 oz) Big bluestem, little bluestem, Indiangrass
    - (2–8 oz) Sideoats grama, blue grama
    - (2–6 oz) Russian wildrye
    - (2–4 oz) Buffalograss

   - Established grasses:
      - (2–12 oz) Big bluestem, little bluestem, Indiangrass, bushy bluestem, King Ranch bluestem, silver beard bluestem, broomsedge, fingergrass (Rhodes grass), needle and thread, kearny (plains) threeawn, prairie threeawn, prairie sandreed, smooth bromegrass, Kentucky bluegrass, Sandberg bluegrass, wheatgrasses, bottlebrush squirreltail, Russian wildrye
      - (2–8 oz) Sideoats grama, blue grama, buffalograss, eastern gamagrass

Glyphosate + Imazapic (Journey®)

The mixture of two herbicides—glyphosate and imazapic—is marketed as a product called Journey, which is labeled for use on rangeland, pasture, and other non-crop areas. The mix incorporates the qualities of both of the individual herbicides but also shares some of the risks as well. Both glyphosate and imazapic can control small, actively growing plants, while the imazapic component provides some soil residual to control pre-emergence of cheatgrass seedlings. The same precautions for non-target plant damage (and even death) that are applicable to glyphosate also apply to the combination of these two herbicides.

- <u>Rate:</u> 12–16 fluid ounces of product per acre
- <u>Timing:</u> Late fall, late winter, early spring (ideally when non-target plants are dormant)
- <u>Restoration considerations:</u> See imazapic and glyphosate sections

Paraquat (Gramoxone Extra®)

Paraquat is in a herbicide group that inhibits photosynthesis and forms free radicals within cells (Group 22). It is one of the most commonly used herbicides in the world but also has a higher level of risk (accidental ingestion of paraquat can be lethal to humans) than many other options. Paraquat is a restricted-use herbicide, which means that a pesticide applicator's license is required for purchase and application. Like glyphosate, paraquat is non-selective and, therefore, capable of damaging or killing desirable plants if applied at sufficient rates at the correct time. It acts quickly on actively growing plant material and is used only as a post-emergent herbicide for cheatgrass. Non-target vegetation will likely be affected by paraquat application. If this is not acceptable for your management goals, another herbicide should be considered.

- <u>Rate:</u> 20–24 fluid ounces of product per acre
   - Special consideration: Do not exceed 24 fluid ounces per acre per year.
- <u>Timing:</u> Apply in spring after 90-percent node formation on cheatgrass
   - Treatment during consecutive years is required for long-term control of cheatgrass
- <u>Restoration considerations:</u> Will damage (and even kill) non-target plants if they have emerged
   - Paraquat does not have soil residual activity and should not affect future seeding of desirable species

Propoxycarbazone Sodium (Canter R+P®)

Propoxycarbazone sodium, marketed as Canter R+P, is another herbicide that inhibits amino acid synthesis (Group 2). It is labeled for use on rangelands, pastures, and Conservation Reserve Program fields. This is a relatively recent addition to the arsenal of potential cheatgrass herbicides. It is labeled for post-emergence control of cheatgrass, specifically when it is actively growing. As with many of the other herbicides, once cheatgrass gets too large, efficacy of control by propoxycarbazone is greatly reduced.

- Rate: 0.9–1.2 ounces of product per acre.
  - » Special consideration: Do not exceed amount of 1.2 ounces per acre per year
- Timing: Apply when cheatgrass is actively growing—before it passes the two-leaf stage
  - » Single application: 1.2 ounces per acre in fall or spring on actively growing weeds
  - » Two applications: fall and spring on active growing weeds. Total of product to equal 1.2 ounces per acre per year
- Restoration considerations: Can cause damage to desirable grass species
  - » Existing native (and other desirable) grass stands: high amounts can cause stunted growth for established grass stands
  - » New seedlings: seed after 90 days of application
    - › Tolerant grass species (see label for more details):
      - – Blue grama, Canada wildrye, crested wheatgrass, Idaho fescue, intermediate wheatgrass, needle and thread, prairie junegrass, Russian wildrye, sand dropseed, Sandberg bluegrass, western wheatgrass, and perhaps others

Rimsulfuron (Matrix®)

Rimsulfuron has a similar mode of action to imazapic, but it is classified as a sulfonylurea-type herbicide (Group 2). Matrix has a supplemental label for use in restoration projects or to manage invasive weeds on non-crop sites. Sites treated with Matrix must be protected from grazing for one full calendar year following application, and no forage or hay should be cut from treated sites during the same period. This is because rimsulfuron is only labeled for non-crop areas or for use in areas where agricultural products are not produced for a full year. Rimsulfuron provides good to excellent pre-emergence and post-emergence control of cheatgrass. Post-emergent control is increased with the use of methylated seed oil, but its use may also increase probability of damage to non-target plants.

- Rate: 2–3 ounces of product per acre
- Timing:
  - » Fall application, before moisture is expected and plant growth occurs
  - » Spring application, before moisture is expected and plant growth occurs. Lower levels of application in the spring provide suppression

        - Do not apply while soil is frozen

- Restoration considerations: If applying 4 ounces of product per acre, wait 7 months after application before seeding. One-half-inch of precipitation at the site increases safety for new seedling emergence of desirable species.

    - Grasses to plant after 7 months:

        - Crested wheatgrass, intermediate wheatgrass, blue bunch wheatgrass, squirrel-tail, beardless (creeping) wildrye, big bluestem, Idaho fescue, smooth brome, and perhaps others

Sulfosulfuron (Outrider®)

Like rimsulfuron, sulfosulfuron is also a sulfonylurea herbicide (Group 2) that inhibits amino acid synthesis. Sulfosulfuron is labeled as Outrider for control of weeds in pastures, rangelands, non-crop areas, and in winter and spring wheat production systems. The label indicates post-emergence control and does not mention any pre-emergent activity.

- Rate: 0.75–1.33 ounces of product per acre (along with a nonionic surfactant)

- Timing:

    - Fall: apply at a rate of 2/3 ounce of product per acre to post-emergence two- to three-leaf cheatgrass plants

    - Spring: apply at a rate of 2/3 ounce of product per acre while cheatgrass is green, is actively growing, and has recovered from cold weather

- Restoration considerations: Labeling indicates that it is safe to plant grasses 14 days after treatment

    - Grasses to plant:

        - Big bluestem, little bluestem, bushy bluestem, blue grama, sideoats grama, buffalograss, Indiangrass, lovegrass, switchgrass, and perhaps others

        - This product should not be applied to new perennial native grass seedlings that are smaller than the three-leaf stage of growth

Sulfometuron + Chlorsulfuron (Landmark XP®)

Landmark XP contains a mixture of two sulfonylurea (Group 2) herbicides. It is labeled for control of cheatgrass and some other weedy species on non-crop sites only (not registered for use in rangelands or pastures). Non-crop sites are areas that are not used for production of food, feed, fiber, forestry, or other agricultural products. Because it is registered as non-crop and not a range and pasture herbicide, sites treated with Landmark XP must be protected from grazing for one full calendar year following application, and no forage or hay should be cut from treated sites during the same period. Landmark usually provides good to excellent control of cheatgrass when applied at the 1.5 ounce-per-acre rate pre- or early post-emergence.

- Rate: 0.75–1.5 ounces product per acre
- Timing:
  » Fall within six weeks of soil freezing or spring within six weeks of spring thaw
  » Spring applications to control cheatgrass that is more than 3–4 inches tall may not be effective
- Restoration considerations: Replant intervals listed on the label include:
  » 3 months for green needlegrass, meadow brome, Russian wildrye, and switchgrass
  » 6 months for western wheatgrass, orchardgrass, meadow foxtail, smooth brome, and sheep fescue

Competitive Seeding (Revegetation)

As with any weed management program, success cannot be defined as simply removing the target weed from the system. Failure to manage for the long-term vigor and persistence of desirable plant species may lead to further site degradation and loss of valuable goods and services from the ecosystem. A control program that results in 100-percent cheatgrass control but also produces significant non-target damage or increases in bare ground may not be acceptable from a land-management point of view. If a site is so degraded that no desirable species remain within the cheatgrass infestation, then reintroduction of desirable species is required (see Restoration section). Selection of these revegetation species should depend on land-use goals. Regarding land-use goals, it is important to consider whether the land will be used for grazing, if species diversity is a concern, and what life forms are desired. In addition to land-use goals, climate, soil suitability, and use of native or introduced species should be considered when deciding which ones to use in revegetation. Another consideration when selecting plant materials for revegetation is whether the selected species are reportedly competitive with cheatgrass. A plant community with a relatively high ability to resist impacts caused by cheatgrass will require fewer inputs and provide increased management benefits over the long term.

A Wyoming study[39] indicates that seeding competitive perennial grasses, without herbicide inputs, may significantly reduce cheatgrass populations. In this study in south-central Wyoming near Riverside, researchers drill-seeded several grass species into an area dominated by cheatgrass and musk thistle. After three years, 'Sodar' streambank wheatgrass, 'Hycrest' crested wheatgrass, and 'Luna' pubescent wheatgrass significantly reduced cheatgrass abundance and produced acceptable levels of forage production on the site. Soil disturbance associated with the drill-seeding may have provided some mechanical control of cheatgrass that was emerged at the time, but the long-term control was primarily attributed to the presence of the competitive desirable grasses.

In many cases, perennial grasses that have been identified as very competitive with cheatgrass are also introduced (i.e., crested wheatgrass and pubescent wheatgrass). The use of native plants in revegetation is a desirable alternative when possible, but until competitive sources of native plants are identified, the use of acceptable introduced species may be an alternative for restoring cheatgrass-dominated sites.

POST-TREATMENT MANAGEMENT

As managers, we tend to focus on the obvious problem: cheatgrass. This problem-oriented focus may cause us to move onto additional sites once a control tactic is implemented and assume that the problem has been solved. A longer-term strategic approach for cheatgrass management recognizes that a single application of a control treatment, regardless of the method, is not likely to result in removal of cheatgrass from the system. As discussed in Chapter 3, this tendency for recurring problems is why continued monitoring of vegetation characteristics is important. Another important component of a strategic cheatgrass management program is a plan for how to manage the site following the implementation of control actions.

Multiple studies from different parts of the West indicate that temporary control of cheatgrass (up to 100-percent control for 2–3 years) can be achieved relatively consistently with herbicide application in areas where cheatgrass was a large component of the community. After this, reinvasion of cheatgrass onto the site has commonly been documented. Managers often assume the reinvasion is driven by the emergence of seed that was persisting in the soil seed bank. However, re-emergence could also potentially be caused by lack of a competitive plant community and immigration of cheatgrass seeds from other sites, as well as other causes such as improper grazing management. Invasion ecology theory suggests that a healthy, diverse plant community that fully uses available resources on the site will be more resistant to invasion, or impacts of invasion, than a site with a depleted desirable plant community. If we carry this rationale forward into a management setting, any management practices we implement that ensure health and vigor of the desirable plant community will potentially prolong the benefit gained from a cheatgrass-control treatment. Utilizing good-grazing-management practices (appropriate utilization levels, alteration of season of use, etc.) are advised whether cheatgrass is a problem or not, and they may be increasingly important when additional investments are made into reducing cheatgrass on the location.

WHAT KIND OF RESULTS CAN I EXPECT FROM A GIVEN TREATMENT?

It is difficult to provide one general prediction of results given variation in soils, precipitation, timing of treatment applications, state of invasion, and other factors. However, we can draw from prior examples to glean what kind of results may occur.

An unpublished study in the early 2000s in northwest Wyoming's Bighorn Basin evaluated the use of Plateau to control cheatgrass several years after a large wildfire burned through the area. The study was conducted in an area that received about 10 inches of rain per year. Untreated, the site produced approximately 720 pounds per acre of cheatgrass and 110 pounds per acre of desirable perennial grasses, characterizing the site as exhibiting a level 5 cheatgrass dominant area. Four ounces of Plateau was applied pre-cheatgrass emergence in the fall (October). This herbicide treatment shifted the forage production to 660 pounds per acre of perennial grasses (a six-fold increase in perennial grasses) and 19 pounds per acre of cheatgrass (a 97-percent reduction in cheatgrass) two growing seasons after application.

In another study in north-central Wyoming near Buffalo, an untreated site produced approximately 500 pounds of cheatgrass and 750 pounds of perennial grasses (primarily western wheatgrass) per acre. Cheatgrass accounted for 40 percent of the grass biomass in this community, which places the untreated site into a level 4 moderate infestation. A fall, pre-emergent application of Matrix resulted in almost 100-percent cheatgrass control one year after treatment. Perennial grass biomass increased to about 1,600 pounds per acre. In relative terms, perennial grass production was nearly doubled by removing cheatgrass from the site.

A pair of experiments completed near Casper and Douglas, in east-central Wyoming, yielded similar results. The untreated plant community was characterized as follows: Casper – 600 pounds per acre of cheatgrass and 700 pounds per acre of perennial grasses (moderate infestation); Douglas – 900 pounds per acre of cheatgrass and 350 pounds per acre of perennial grasses (cheatgrass dominant). Each site was treated with 6 ounces of Plateau during a fall, pre-emergent application. The following growing season, treated areas yielded: Casper – 0 pounds per acre of cheatgrass and 1,230 pounds per acre perennial grasses; Douglas – 20 pounds per acre of cheatgrass and 630 pounds per acre of perennial grasses. At both sites, perennial grass production was nearly doubled, and cheatgrass control was approaching 100 percent.

Data from an ongoing study north of Douglas assessed the use of Plateau at 6 ounces per acre after implementing a prescribed fire. Cheatgrass cover was relatively low prior to the fire (approximately 1–2 percent), which would put the site in the trace level of cheatgrass invasion. Five years after the fire, areas treated with herbicide were still in the trace cheatgrass invasion state, while untreated areas had progressed to the mild infestation state of invasion (approaching 10-percent cheatgrass cover). This observation may indicate that treating infestations early in the invasion process could lead to long-term management of cheatgrass prior to the development of a persistent seed bank. It may also indicate that the sites within the study were not suitable habitat for cheatgrass to become a dominant species. More research is needed to better understand these dynamics.

CONCLUSION

There are many tools for controlling cheatgrass, and the effectiveness of each tool depends on the situation in which it is used. Selecting a strategy that fits within management objectives, is appropriate for the level of infestation and condition of desirable plants on the site, and is economically feasible is crucial for long-term success. Land managers should balance the potential increases in forage production and longevity with the estimated costs of treatment. Currently, there is no one-time treatment that ensures the long-term removal of cheatgrass from a system, so a multiple-year, adaptive-management strategy that emphasizes the vigor of desirable plants is warranted.

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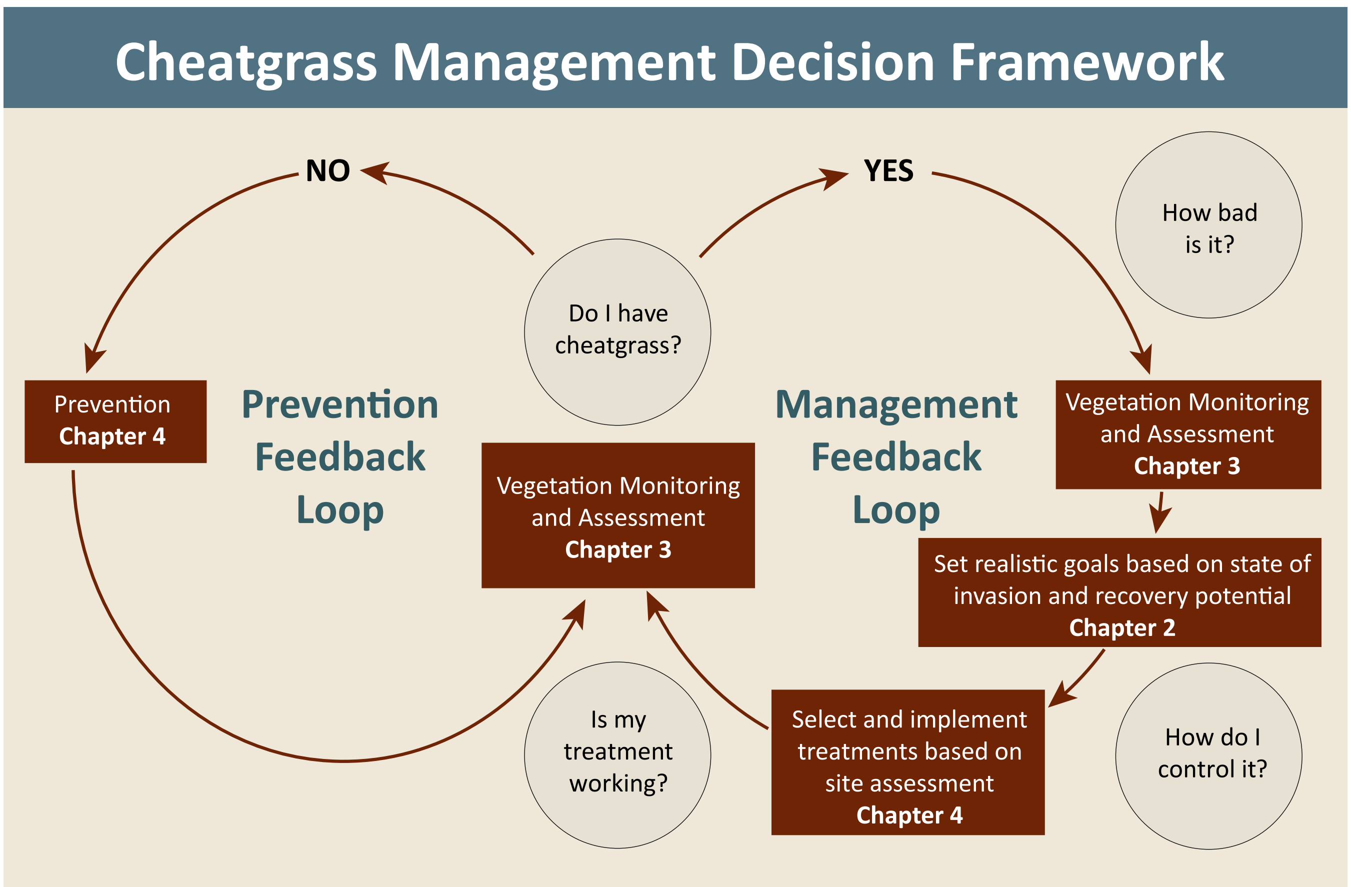
Brian A. Mealor

Chapter 5

Scenarios



Chapter 5 – Scenarios

This handbook has discussed methods for strategically managing cheatgrass infestations based on a series of principles and steps:

- Vegetation monitoring informs management decisions;
- Increasing severity of cheatgrass infestation requires greater effort to manage;
- Management actions should consider position on the landscape and recovery potential; and
- Management actions depend on site-specific characteristics and goals.

In this chapter, we present a series of scenarios to illustrate the kind of results that have been seen in previous projects. The scenarios vary in level of cheatgrass infestation and desirable plants on-site, land-use goals, and management tactics. Although some of the details, especially regarding the identity of the people in the scenarios, are fabricated, the vegetation data and plant responses to treatments are all based on real information from field trials.

All scenarios provide information regarding each step of the cheatgrass management process: goals, vegetation assessment to determine level of invasion, management approach, and post-treatment vegetation monitoring to determine progress toward goals. Perhaps you will find that one of the scenarios is similar to a situation you face.

MODERATE INFESTATION – AGGRESSIVE MANAGEMENT

James runs a herd of beef cattle on his small southeastern Wyoming ranch near Lingle. James notices a small patch of cheatgrass covering about five yards along a road in one of his pastures. He, unfortunately, decided not to worry about the problem for the time being. Over the years, the cheatgrass population began to spread along the road until it could be seen throughout the pasture. James notices that his livestock are not willing to utilize the pasture to the same degree as they had in previous years, so he decides it's time to take action. His goal is to reduce the cheatgrass cover while promoting the native perennial grasses that his cattle prefer.

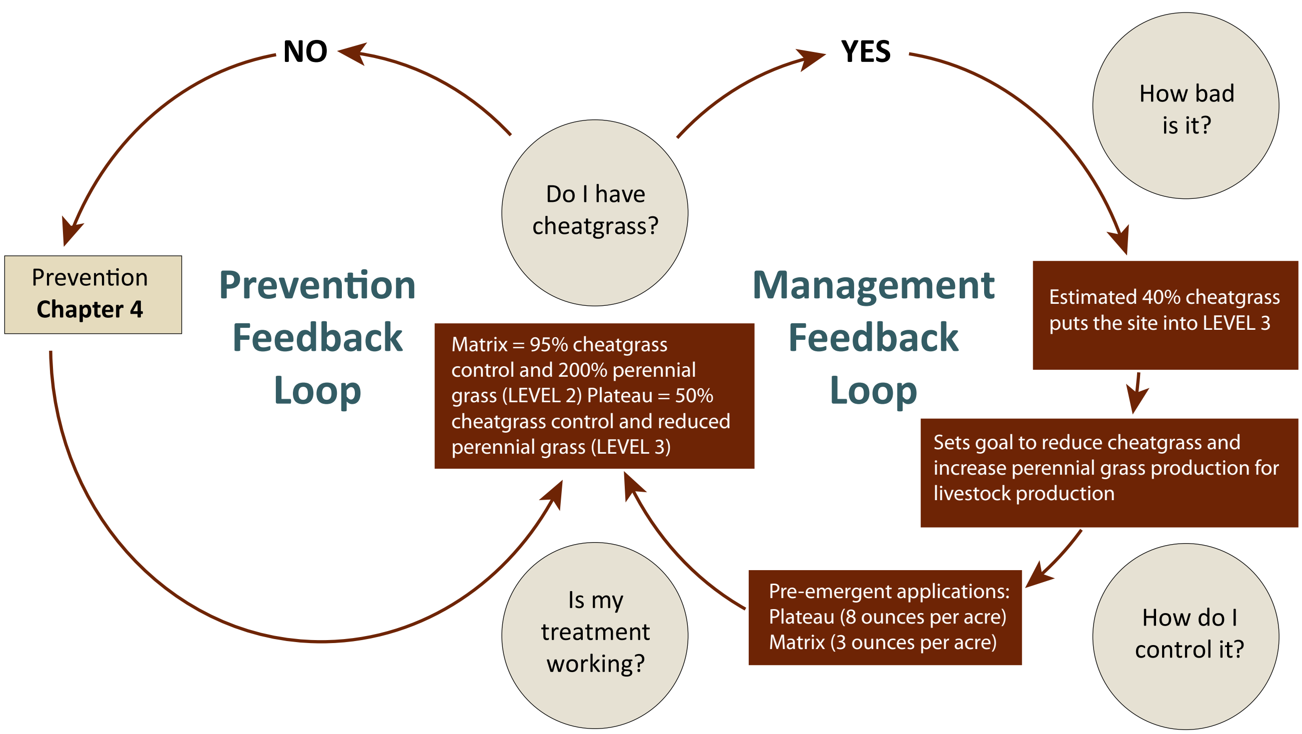
James begins with a pre-treatment assessment to document the current condition of his pasture. He finds that the dominant desirable plants in his pasture are needle and thread (*Hesperostipa comata*), alkali sacaton (*Sporobolus airoides* Torr.), prairie sandreed (*Calamovilfa longifolia*), and western wheatgrass (*Pascopyrum smithii* Rydb.). He also finds that cheatgrass is uniformly distributed across his pasture at about 40-percent cover (a moderate infestation). With the help of his friend, Brandon, a Natural Resources

Conservation Service range conservationist, he discovers that the soil in his pasture is a Haverson and McCook loam, and that the ecological site of his ranch is Loamy Lowland. With the pre-treatment assessment complete, James decides he will use herbicide to treat the cheatgrass.

James learns of two range-approved herbicides that have shown to be effective on cheatgrass, Plateau and Matrix. Rather than using only one herbicide for his whole pasture, James decides to test the two herbicides on different portions of his pasture to determine which one will be more effective. This way, he will only spend money on large quantities of the herbicide that is most effective overall. He selects a rate of 8 ounces for Plateau and 3 ounces for Matrix based on the labels and applies each herbicide using a calibrated hand sprayer. In the fall, he applies each herbicide, being careful to set aside a few control plots. The next summer, Brandon assists James in clipping plants to determine biomass, making visual control ratings, and determining vegetative cover.

James finds—compared to the controls—he achieved about 95-percent control of cheatgrass in addition to doubling perennial grass biomass in the areas treated with Matrix. On the other hand, he only achieved about 50-percent control of cheatgrass while perennial grass biomass was reduced in the area where he applied Plateau. Based on the success he has seen with Plateau in the past, these results surprise Brandon; however, he concludes that perhaps conditions at his site did not lead to effective performance of Plateau. James decides to use Matrix on the rest of his pasture and to continue with assessments as part of his monitoring program. This will help ensure continued success and prevent the spread of cheatgrass into his other pastures.

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



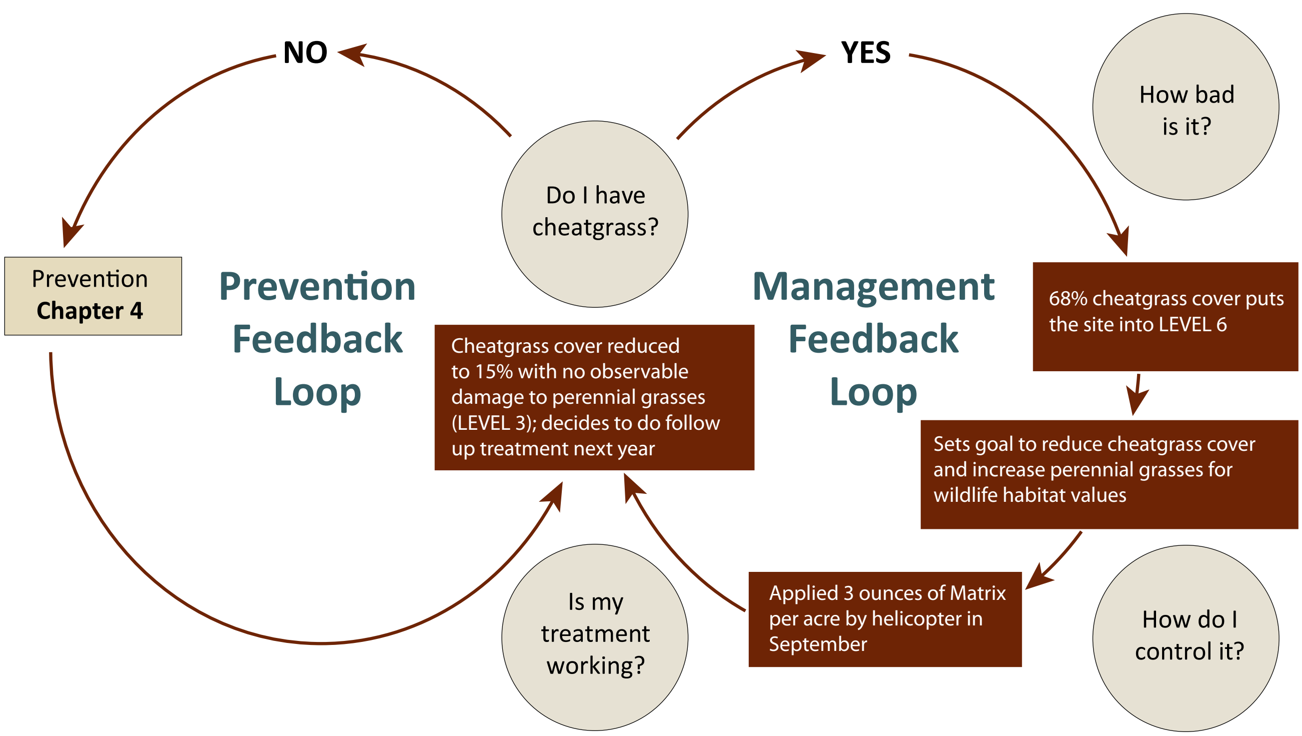
CHEATGRASS DOMINANT – AGGRESSIVE MANAGEMENT

Julian manages a wildlife habitat area in Sublette County, western Wyoming, that is approximately 640 acres. The land is managed for not only wildlife but livestock grazing and hunting, as well. The property sits at an elevation of 7,500 feet and has an average growing season of 45 days. When Julian took over managing the property in 2010, she noticed that cheatgrass was prolific on the property. This was surprising, as she had previously heard that there was little to no cheatgrass in the county.

Julian decides to collect baseline cover data (by species) along a southeast aspect of the property in early August 2011. She collected line–point intercept data along two, 25-meter transects every ½ meter for a total of 50 points per transect. Julian noted smut (a plant disease caused by fungi of the order *Ustilaginales*) on some cheatgrass within the areas used for pre-assessment. The aggregated cover data by grass species was: cheatgrass, 68 percent; needle and thread (*Hesperostipa comata*), 40 percent; bluebunch wheatgrass (*Pseudoroegneria spicata*), 18 percent; and Indian ricegrass (*Achnatherum hymenoides* Roem. and Schult.), 7 percent. Julian encountered a number of forbs along her transects, too, including milkvetch (*Astragalus* sp.), balsamroot (*Balsamorhiza* sp.), along with pricklypear (*Opuntia* sp.). She noted other species that were on the site, but not intercepted during data collection including sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia* sp.), and pussytoes (*Antennaria* sp.).

Julian's data verify her concern that the site is experiencing a dominant level of cheatgrass invasion. She decides to develop a cheatgrass management plan, which includes her goal to reduce the cover of undesirable annual grasses (i.e., cheatgrass) while increasing the cover of desirable perennial species. In implementing her plan, Julian applies 3 ounces of Matrix per

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



acre plus a surfactant at 1 percent based on her prior experience and the herbicide label. The herbicide was applied to 150 acres by helicopter on September 1, 2011.

Julian returns to the treated area in mid-June 2012 to collect post-treatment data along her original transects. The native, perennial grass cover detected was about the same as that detected during the pre-treatment assessment, with one new species detected, western wheatgrass (*Pascopyrum smithii* Rydb.). Julian, however, was surprised to find that cheatgrass cover was reduced to 15-percent post-treatment. Previously, she had used Matrix and received 100-percent control of cheatgrass one year post-treatment. Julian wonders if the warm fall and mild winter affected the performance of the Matrix. She decides to treat the same area again in fall 2012 with Matrix. She will monitor the location again in 2013 and reassess the area and decide how to proceed with management.

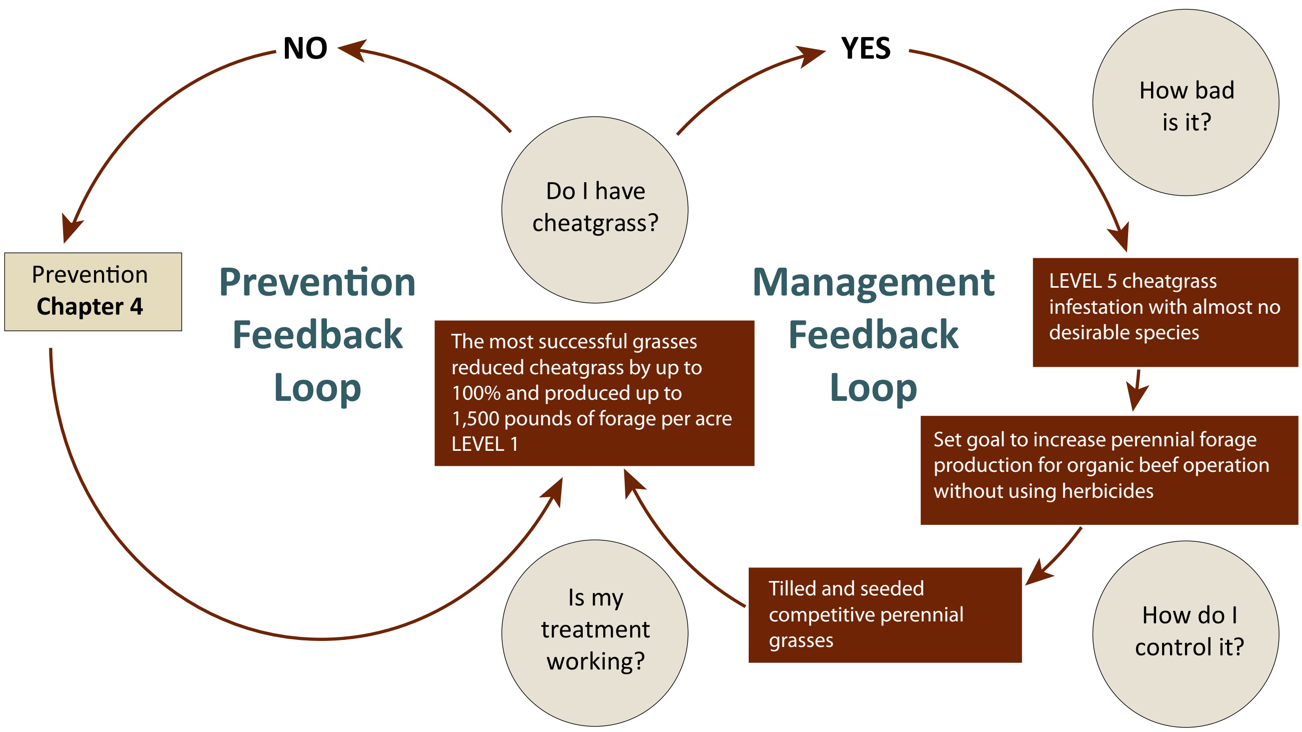
CHEATGRASS DOMINANT – RESTORATION

Bodie and Raul are land managers for a growing cattle operation in south-central Wyoming. They acquired a very inexpensive 400-acre certified organic pasture from the previous owner. Many years ago the site was farmed, but later it was abandoned and never reseeded. Now, the land was being offered for such a low price because it was cheatgrass dominated. The only species present on the site was cheatgrass, producing 1,195 pounds of annual production per acre, along with a limited presence of musk thistle (also known as nodding plumeless thistle [*Carduus nutans* L.]). The area receives about 14 inches of annual precipitation, and the soils are a fine to coarse loam.

Bodie and Raul want to intensively graze this pasture for a short duration once in early spring and once in mid-spring each year. For this reason, they wanted to replace cheatgrass with more productive perennial grasses that have a longer period of palatability. As the land was already certified for organic beef production, Bodie and Raul decided to keep it organic and not use herbicides for cheatgrass control. Their pre-treatment assessment uncovered no desirable species, so it was necessary to bring desirable seeds back into the system through a seeding treatment (restoration). To achieve their spring grazing goals, they decided that the best species to use would be competitive cool-season bunchgrasses. Specifically, they seeded 'Luna' pubescent wheatgrass, 'Hycrest' crested wheatgrass, 'Sodar' streambank wheatgrass, and 'Critana' thickspike wheatgrass at a rate of 9.7 pounds per acre. Additionally, they added 'Bozoisky' Russian wildrye at a rate of 5.4 pounds per acre. To prepare the site, Bodie tilled the pasture during the growing season—just prior to cheatgrass seed set—to disrupt growth and reduce invasive seed input. The tilling practice also helped prepare the soil for seeding. Bodie and Raul were curious about which species would work at their site. Rather than mixing the grasses, each species was seeded alone in different strips. They also decided to leave an area unseeded as a control strip to compare to each seeding treatment.

After three years of monitoring, Bodie and Raul found that they were able to reduce cheatgrass and increase the perennial grasses in their pasture compared to the unseeded controls. They also found that the species they planted performed differently. The most successful species were pubescent wheatgrass and crested wheatgrass. These reduced the growth of cheatgrass through competition (100-percent and 91-percent control of cheatgrass, respectively) as well as having the highest production values (1,529 and 1,424 pounds per acre, respectively). Bodie and Raul were also pleased to discover that one of the native cultivars, streambank wheatgrass, also provided good control of cheatgrass (85 percent), even if its production was lower than other species (1,012 pounds per acre). The other two grasses, thickspike wheatgrass and Russian wildrye, provided limited cheatgrass control. Bodie and Raul were happy to find a management option for their cheatgrass-dominated pasture that allowed them to adhere to their organic requirements.

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



MILD INFESTATION – LONG-TERM MANAGEMENT

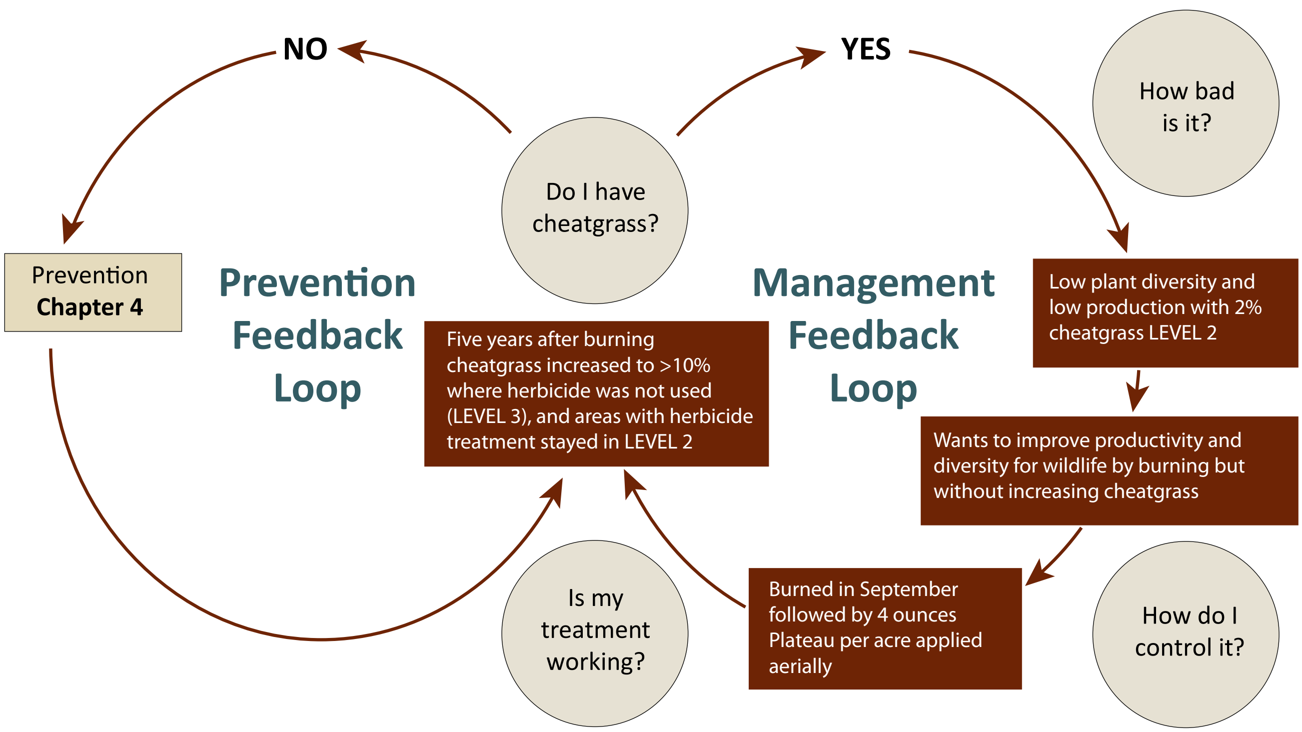
Bill, a rancher in eastern Wyoming, manages his property for both livestock production and wildlife habitat. His ranch is located near, but not within, a greater sage-grouse core area. This particular species of grouse is one of the high-priority wildlife species within his management plan. He implements a rotational grazing system for his sheep and cattle operations. The property sits within a 10- to 14-inch average precipitation zone and contains a mix of sandy–loam, clay, and loamy soils.

In an effort to improve forage production and diversity of herbaceous species (forbs and grasses) in one of his pastures, Bill implements a prescribed fire. Prior to burning the pasture, his long-term monitoring program indicated a low presence of cheatgrass (approximately 2-percent cover) and perennial grass cover (about 15 percent) including needle and thread, Sandberg bluegrass, blue grama, and western wheatgrass. This vegetation information placed the pasture in the “trace” level of cheatgrass abundance.

Since Bill was aware of the relationship between cheatgrass and fire, he was concerned that burning may lead to an increase in cheatgrass following the fire. In an effort to reduce the risk of increased cheatgrass after burning, Bill decided he would follow the prescribed fire with an herbicide application. The pasture was burned in early September, and an application of Plateau at 4 ounces of product per acre was applied prior to cheatgrass emergence in October. Before applying herbicide, Bill waited until the majority of the ash was cleared (by wind) from the soil surface as carbon-rich ash may reduce the efficacy of soil-applied herbicides such as Plateau. Bill also decided to leave a relatively small portion of the treatment area as a “control,” in which no herbicide was applied. He did this to satisfy his curiosity about whether he needed the herbicide treatment or not.

After the burning and herbicide treatments, Bill and his family continued to monitor vegetation in the pasture. Five years after the fire, areas treated with herbicide were still in the trace cheatgrass invasion state while untreated areas had progressed to the mild infestation state of invasion (cheatgrass exceeding 10 percent). These observations may indicate that treating infestations early in the invasion process could lead to long-term management of cheatgrass prior to the development of a persistent seed bank. An alternative explanation could be that Bill’s pasture did not provide habitat suitable for cheatgrass to become a dominant species. Only continued monitoring of vegetation can address this unanswered question.

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



MODERATE INFESTATION – LONG-TERM MANAGEMENT

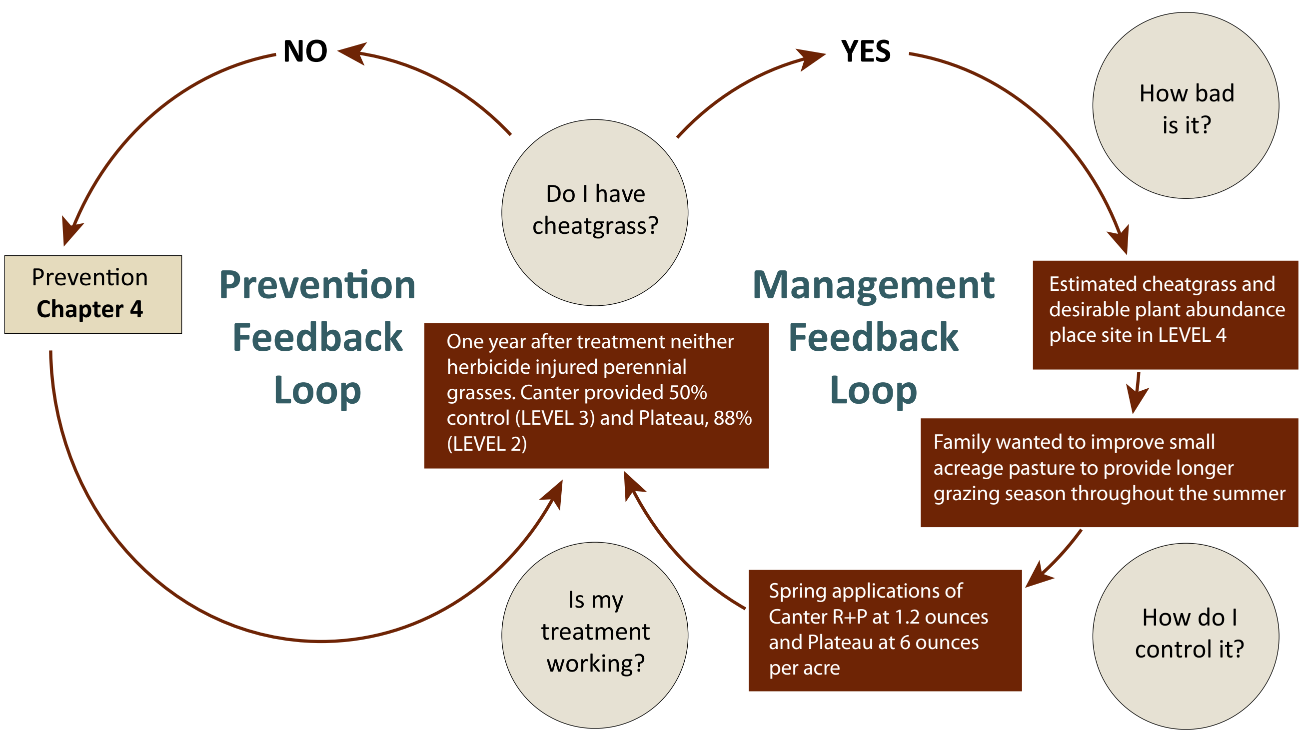
Frank and Kim Smith purchased a small-acreage property in north-central Colorado. Here, they plan to keep a few cattle and horses, mostly for their kids’ 4-H projects. After attending a pasture-management workshop hosted by the local conservation district and Colorado State University Extension, the Smiths take a closer look at their pasture. They were primarily concerned with providing forage throughout the year for their small group of livestock but also wanted to maintain the stability of the soil to avoid erosion.

When spring arrived, Frank, Kim, and the kids established several monitoring transects in their pasture. After completing a pre-treatment assessment, they discovered that much of the grass emerging was cheatgrass. They documented cheatgrass at densities up to 200 plants per square foot. Perennial grasses were still present (primarily crested wheatgrass and smooth brome) but scattered throughout the pasture. This community composition placed the pasture in the moderate level of cheatgrass infestation.

The Smiths had read about two different herbicides and decided to try Plateau at 6 ounces per acre in one area of the pasture and Canter R+P at 1.2 ounces per acre in another area to see which would be more effective. They also left a control area untreated to serve as a direct comparison between the effects of herbicide and not applying a treatment. The Smiths made their herbicide applications in early April on a morning when the wind was calm and the temperature was about 60°F. At this time, cheatgrass was actively growing and at the four-leaf to three-tiller stage. Because cheatgrass had already emerged, they included a quality, non-ionic surfactant to ensure adequate herbicide movement into the plants. Perennial grasses in the pasture were approximately 2–3 inches in height and had already experienced some grazing pressure.

The Smiths evaluated their treatment areas regularly during evening walks. First, they saw some stunting and thinning of cheatgrass in the areas treated with herbicides. One month after treatment, they noticed some of the cheatgrass was dying, and the perennial grasses had no signs of injury. After two months, cheatgrass control increased to more than 90 percent as a result of both herbicides. Frank and Kim were happy about these results.

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



The next year, Frank and Kim monitored their pasture again to see if the treatment was still effective. The area treated with Canter R+P, which had yielded 92-percent cheatgrass control in the year of treatment, only reduced cheatgrass by about 50 percent in the year after treatment. The Plateau-treated area, though, had approximately 88 percent less cheatgrass in the year after treatment. Neither of the herbicide treatments appeared to have injured perennial grasses in the pasture.

MODERATE INFESTATION – AGGRESSIVE MANAGEMENT

Dale runs a herd of Hereford cattle on his central Wyoming ranch near Casper. The property receives between 10 and 14 inches of precipitation on average each year, and the majority of the soils are sandy. Because his property is located in an area that has sandy soils, maintaining vegetation cover is paramount if he wants to keep his topsoil in place. Besides maintaining vegetation cover, Dale also hopes to increase the amount of desirable grasses and increase the gain on his cattle.

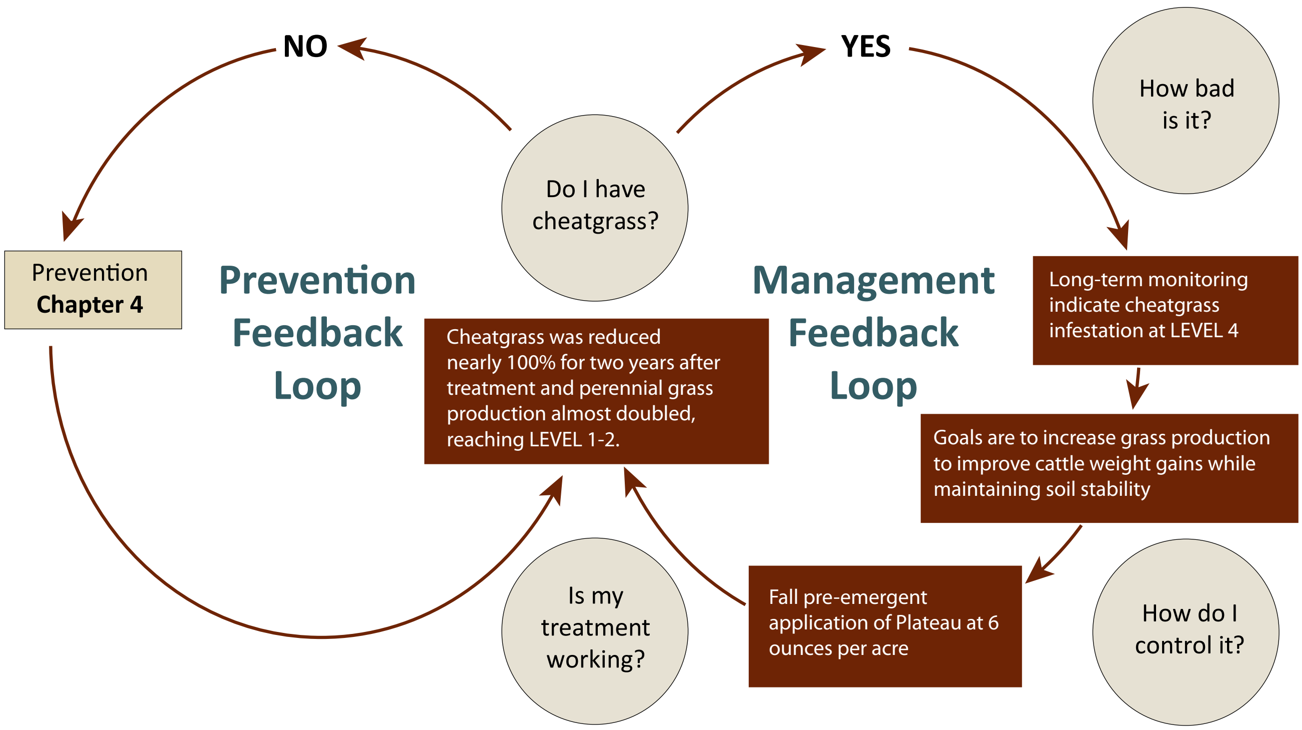
Fortunately, Dale has always been adamant about monitoring his pastures for annual use and long-term trend. Unfortunately, these data indicate a persistent population of cheatgrass that has now reached a moderate infestation level (26–50 percent). Dale also has cactus to contend with, but his biggest priority is management of the cheatgrass infestation. He sees promise in his perennial vegetation that is largely made up of blue grama, needle and thread, Sandberg bluegrass, and upland sedge. He is hopeful that by decreasing the amount of cheatgrass on his property, he will begin to see an increase in some of these more desirable plants.

After consulting with University of Wyoming Extension, he decides on a herbicide treatment to try and stop the progression of cheatgrass and enable his perennial grasses to respond. He was advised to try the herbicide Plateau. In the fall, Dale applied 6 ounces of Plateau on areas infested with cheatgrass. He was also advised to leave a small area in which no Plateau was applied. This control plot would aid in determining the impact of Plateau on cheatgrass.

The following spring, Dale went out to assess the impact of the herbicide. The untreated area of the pasture had about 600 pounds per acre of cheatgrass and 700 pounds per acre of perennial grasses. To Dale's delight, the herbicide treatment decreased the cheatgrass to 0 pounds per acre, while perennial grass production climbed to 1,230 pounds per acre. Dale was quite excited by these results but was curious as to what would happen down the road.

Two years after the initial Plateau treatment, Dale evaluated his cheatgrass infestation again. He was eager to see what had happened because that year was one of the driest he had ever endured. The untreated area had 150 pounds per acre of cheatgrass and 300 pounds per acre of perennial grasses. There were only 6 pounds per acre of cheatgrass and 730 pounds per acre of perennial grasses in the area treated with Plateau. Overall, perennial grass production nearly doubled, while cheatgrass control was still approaching 100 percent.

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



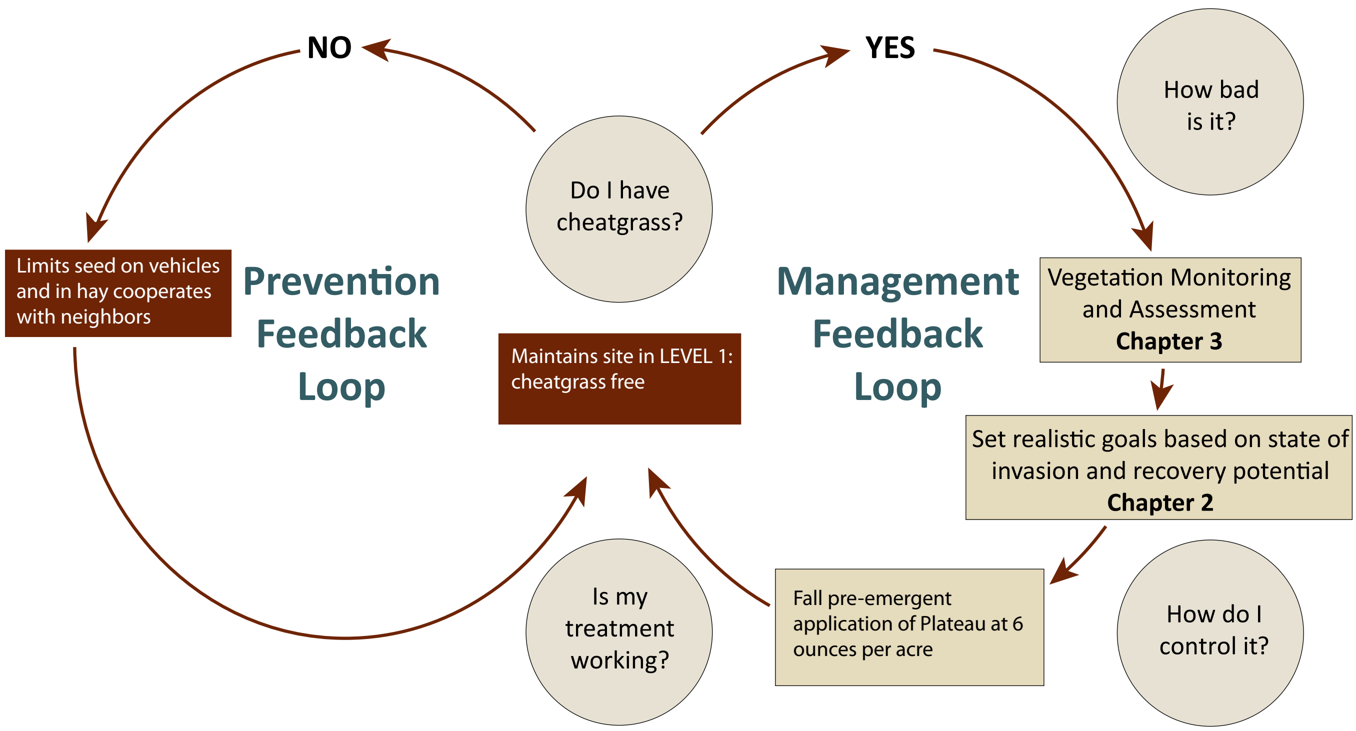
CHEATGRASS FREE – PREVENTION

There is currently little data on prevention areas, so we offer a hypothetical scenario to illustrate the principles of prevention. Charlie, a private landowner in central Wyoming, knows that invasive cheatgrass is spreading and increasing in abundance throughout the area. She currently uses her small ranch to graze cattle and understands that cheatgrass invasions can reduce desirable grass yield. Since Charlie's main goal is to maintain and increase palatable biomass, the idea of cheatgrass on her site is undesirable. Even though she has a strict management plan in place, Charlie decides to increase monitoring to detect any cheatgrass invasions now and in the future. She also understands that monitoring for and, consequently, managing weed populations in their initial stages of invasion is cheaper and more likely to be successful. Charlie completes an assessment of invasive and native biomass cover and finds that the majority of her land falls into the "cheatgrass free" level of invasion. This is great news; however, the cheatgrass patches she notices on neighboring lands are troubling.

To safeguard her own land, Charlie begins a plan to increase highly competitive desirable grasses near fence lines to reduce the likelihood of cheatgrass moving into those areas. This competitive seeding action also helps form green strips to reduce fuel loads in case of a cheatgrass fire. Next, Charlie tries to limit the potential for her livestock (via seeds in fur or digestive systems) and herself (via equipment, shoes, and truck) to transport cheatgrass seeds from any areas where it is present. Charlie also plans to purchase hay only from producers with certified weed-free fields to limit cheatgrass seed transport (she talks with the suppliers specifically about cheatgrass not being in the hay). Finally, Charlie works with her neighbors to manage the existing cheatgrass populations in order to contain invaded areas, especially those areas more likely to be invaded (i.e., south-facing slopes and areas closer to distribution sites like roads and disturbed sites). In fact, Charlie and her neighbors have discussed forming a cooperative weed management area that will focus on cheatgrass and other problematic weed species in the area.

Charlie's effort to reduce cheatgrass spread from neighboring land and seed sources helps her achieve her goal of maintaining high yield of desirable forage. Constant monitoring also allows rapid identification of new populations of cheatgrass and efficient population removal, keeping her land largely cheatgrass free. Additionally, through continued communication with neighbors, Charlie ensures that cooperative management continues.[1,2]

CHEATGRASS MANAGEMENT DECISION FRAMEWORK



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Chris Evans, Illinois Wildlife Action Plan, Bugwood.org

Glossary

Abundance: the total number of individuals of a species in an area, population, or community

Acclimatized Species: an introduced species that has become adapted to a new climate or a different environment and can perpetuate itself into the community without cultural treatment; see "exotic" and "introduced species"

Alien: see "exotic"

Annual Plant: a plant that completes its life cycle and dies in one year or less

Assessment: evaluation of the vegetative composition and species abundance of a site to provide land managers with information regarding the condition of the site at that particular point in time

Awn: bristle growing from the upper tip of a glume or lemma (part of a floret); usually an extension of a nerve

Biennial Plant: a plant that lives for two years, producing vegetative growth the first year and usually blooming or fruiting in the second year and then dying

Biological Control: reduction or management of pest populations using natural enemies; typically involves an active human role (such as introducing an insect herbivore)

Boot Stage: developing seedhead but still contained within the leaf sheath of the uppermost leaf

Bract: modified leaf or scale, often associated with a floral portion of a plant

Collar (Leaf): region of the outside of a leaf at the junction of the blade and the sheath, frequently having a different appearance than the rest of the leaf

Community: a general term for an assemblage of plants and/or animals living together and interacting among themselves in a specific location; no particular successional status is implied

Community (Plant): An assemblage of plants occurring together at any point in time, while denoting no particular successional status; a unit of vegetation

Composition (Species): the proportion of various plant species in relation to the total on a given area; it may be expressed in terms of cover, density, weight, etc.

Control Plots: the standard or non-treated plots in an experiment to better evaluate treatment responses

Cover: the proportion of the ground covered by a vertical projection of the outermost perimeter of a plant's foliage; can consider (1) basal cover: the area of the ground surface covered by the base of a plant; or (2) canopy cover: the ground surface covered by the plant when looking down from above

Culm: aerial stem of a grass

Degradation: subtle or gradual changes that reduce ecological integrity and health

Denitrification: removal of nitrogen or nitrogen groups from a compound, such as bacterial action in the soil reducing nitrates/nitrites to nitrogen-containing gases

Density: numbers of individuals or stems per unit area; density does not equate to any kind of cover measurement

Desirable Plant Species: species that contribute positively to the management objectives

Desired Plant Community: of the several plant communities that may occupy the site, the one that has been identified through a management plan to best meet the plan's objectives for the site

Diversity: the distribution and abundance of different plant and animal communities within an area

Dormancy (Seed): live seed in a non-germinative condition because of (1) internal inhibitions in seed, i.e., hard seed, or (2) unfavorable environmental conditions

Ecological Site: a kind of land with specific physical characteristics that differ from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its response to management

Ecological Threshold: point in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained equilibrium of the state degrades beyond the point of self-repair; crossover point where an ecosystem changes to a new state

Ecology: the study of the interrelationships of organisms with their environment

Ecosystem: organisms, together with their abiotic (non-living) environment, forming an interacting system and inhabiting an identifiable space

Eradication (Plant): complete kill or removal of a noxious plant from an area, including all plant structures capable of sexual or vegetative reproduction

Exotic: an organism or species that is not native to the region in which it is found; syn. *Alien*

Fibrous Root System: a plant root system having a large number of small, finely divided, widely spreading roots, but no large taproots; typified by grass root system

Flexuous: bent alternately in opposite directions but not strongly so

Floret: seed unit composed of the lemma and palea with enclosed pistil and stamens, if any are present

Forage: browse and herbage that is available and may provide food for grazing and browsing animals or be harvested for feeding livestock and/or wildlife

Forage Production: the weight of forage that is produced within a designated period of time in a given area; the weight may be expressed as either green, air-dry, or oven-dry; the term may also be modified as to time of production such as annual, current year, or seasonal forage production

Frequency: the ratio between the number of sample units that contain a species and the total number of sample units

Germination: the emergence of a root and/or shoot from a seed coat

Glabrous: hairless; sometimes used in place of smooth

Glume: one of a pair of bracts found at the base of the spikelet and not containing pistils or stamens; occasionally one or both glumes are absent

Goal(s): a single statement that describes a desired end result; a big picture view of the land

Human Dimensions: an individual's or a culture's values, interests, and perspectives about socio–economic, political, and ecological topics

Hybrid: offspring of a cross between genetically dissimilar individuals

Inflorescence: spikelets and the axis or branches bearing them

Introduced Species: a species not a part of the original fauna or flora of the area in question

Invasion: the migration of organisms from one area to another area and their establishment in the latter

Invasive Species: an introduced species that establishes and spreads, unaided, into natural environments; often associated with ecological or economic impacts

Lanceolate: shape of a leaf; much longer than wide, widest below the middle and tapering toward both ends (sometimes rounded at the base)

Ligule: membranous or hairy structure on the inside of a leaf at the junction of the sheath and the blade

Litter: the uppermost layer of organic debris on the soil surface; essentially, the freshly fallen or slightly decomposed vegetative material

Mycorrhizal Fungi: symbiotic and generally mutually beneficial relationship between fungi and plant roots where the fungi receives carbohydrates and, in turn, increases the plant's ability to obtain water and nutrients

Monitoring: the orderly collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives; this process must be conducted over time to successfully determine whether management objectives are being met

Native Species: a species that is part of the original fauna or flora of the area in question

Naturalized Species: a species not native to an area but which has adapted to that area and has established a self-sustaining population; does not require artificial inputs for survival and reproduction

Niche: the ecological role of a species in a community

Noxious Weed: a legal designation for a plant species determined to be detrimental to general health and welfare of a state, typically because it harms livestock, carries diseases or parasites, or negatively affects management of agricultural or natural systems

Objectives: links between goals and what will be done to achieve them; they include specific details about what can be done and what can be measured as well as an estimated time frame for completion

Panicle: inflorescence consisting of a main axis with branched branches

Pedicle: stalk of a spikelet

Perennial Plant: a plant that has a life span of three or more years

Phenology: the study of periodic biological phenomena that are recurrent such as flowering, seeding, etc., especially as related to climate

Phenotypic Plasticity: ability of a single genotype (genetic code) to exhibit a variety of phenotypes (observable characteristics or traits) in different environmental conditions

Photoplot: a close-up photograph of a defined area (small plot)

Photopoint: a landscape-orientation photograph taken from a permanent reference location and taken at periodic intervals

Pure Live Seed (P.L.S.): purity and germination of seed expressed in percent; may be calculated by formula: P.L.S. = % germination * % purity ÷ 100, e.g., = 87.36%

Quadrat: physical sampling units placed over vegetation to act as boundaries for sampling

Restoration (Ecological): the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed; any management strategy that requires the active human reintroduction (via seeding, transplanting, etc.) of desirable plants onto the site

Rhizomes: a horizontal underground stem, usually sending out roots and aboveground shoots from the nodes

Sampling Unit: the unit on which the actual measurement of a characteristic is made; can be a quadrat, transect, etc.

Seed Bank: viable seeds incorporated into the soil and litter layer of an area

Senescence: aging in plants

Sheath (Leaf): tube-shaped lower part of a leaf placed below the blade and surrounding the culm

Spikelet: unit of the inflorescence of a grass

Tiller: the asexual development of a new plant from a meristematic region of the parent plant

Transect: lines used to help determine where to locate quadrats to test for changes along environmental gradients

Trend: the direction of change in an attribute as observed over time

Utilization: the proportion of current year's forage production that is consumed or destroyed by grazing or browsing animals; may refer either to a single species or to the vegetation as a whole

Weed: any plant growing where unwanted; a plant having a negative value within a given management system

Vegetation Attributes: characteristics of vegetation that describe how many, how much, or what kinds of plant species are present

Vernation: the arrangement of a leaf in the bud

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Jan Samanek, State Phytosanitary Administration, Bugwood.org

Appendix A.

Techniques for Collecting Vegetation Data

The methods outlined in Appendix A represent some of the many methods available and are guides (not standards) for sampling vegetation attributes. They have been selected for their applicability in assessing and monitoring areas impacted by cheatgrass populations. Several references were used in the development of Appendix A[1–3].

Techniques will assist in determining whether goals are being met. Vegetation attributes will be determined based on the goals and objectives set. Vegetation attributes are characteristics that are determined when vegetation data are collected using methods outlined in this appendix. Below is a list of attributes that can be determined or collected using the techniques described.

Frequency

Frequency is a characteristic of how common a species is within a management unit. This attribute is related to the distribution of a plant species. It can be useful in detecting changes in plant communities over time.

Utilization

Utilization is a vegetation attribute that reveals the percentages of annual forage production removed by grazing or browsing animals. Collecting residual measurements and utilization data is important to determine effects of grazing on a vegetation community. Utilization measurements can assist in identifying use patterns and establishing cause-and-effect interpretations of rangeland trend data. With other monitoring data, utilization measurements can also help determine or make adjustments to stocking rates to ensure appropriate levels for each area. Maintaining appropriate utilization levels helps to ensure the survival of healthy, desirable plants that can better compete with cheatgrass.

Density

Density is the number of individuals of a species of interest in a given unit of area. It is important to define the counting unit when using density. The unit has to be consistently recognized by all observers for accurate monitoring.

Cover

Cover is a measure of the percentage of ground surface covered by vegetation. It is a good idea to sample vegetation during the same stage of plant growth during each measuring event. This is because cover can dramatically change over the growing season. Keep in mind that stages of plant growth will not likely occur on the same calendar date because of the variation in climatic conditions from year to year. Common techniques use lines, points, or plots to measure cover, and all approaches have been used for decades.

Composition

Species composition is an attribute that is calculated to determine the proportions of various plant species in relation to the total for a given area. Composition can be expressed in terms of cover, density, weight, etc.

Forms listed within the equipment sections can be found in Appendix B for all of the techniques discussed. Forms are provided for use in the field.

I. STANDARD MONITORING PRACTICES

Many of the assessment and monitoring methods described below have numerous common elements that will be discussed. These common aspects can be easily incorporated when conducting an assessment or follow-up monitoring program regardless of the method selected to collect vegetation data.

Site Selection

Monitoring sites should be selected and agreed upon by all vested interests before a project begins. Key areas should generally represent the entire study area; however, specific objectives may be developed, in this case to manage cheatgrass populations and to monitor specific critical areas. Keep in mind that data from critical sites should not be accepted as a representation of the entire study area.

Most importantly, the selection of key or critical areas should depend on the management objectives determined by vested interests. Ideally, monitoring sites should be easy to find and readily accessible. It is important that all those involved know the site locations and how the data will be gathered and used. A Site Information Sheet should be used when any of the methods outlined below are conducted (see Appendix B). This will provide documentation of the location and general characteristics of a site.

Permanently marking the study location

Permanently mark the location of each study using a reference post (steel post) positioned

Brian A. Mealor

Figure A-1. Example of a photopoint image with a Site Information Sheet held.

approximately 20 feet from the study location (i.e., the beginning of a transect) where data will be collected. Livestock will often rub on the reference post, damaging vegetation in the immediate vicinity, which can skew data if the study location is not distanced from the post. Document the bearing and distance from the post to the study location or select a reference point (prominent natural or man-made feature), and, again, record the bearing or distance from that point to the study location. This will help with finding the study location once the reference post has been relocated (Fig. A-1).

After placing a reference post, permanently mark the study location directly by driving PVC pipe (with a cap) or angle iron at randomly selected starting points. If a transect will be used, both ends of the measuring tape should be permanently staked. You can also mark the transect location stake with a bright-colored spray paint, and document the point using a global positioning system (GPS) unit to help in relocation.

Study documentation

Documentation is crucial in obtaining consistent assessment and monitoring data. Record the study and transect locations, number of transects, starting points, bearings, length, distance between transects, number of quadrats, sampling interval, quadrat frame size, number of cover points per quadrat frame, and other pertinent information regarding the study on the Site Information Sheet.

For ease of finding site locations, document the exact location of the study site and the directions for relocating it. This will save time when relocating sites year after year. Also, plot the location of the study on a detailed map or aerial photographs, if possible.

General observations can also be important to include within an assessment or monitoring plan. Observations regarding climate conditions, grazing management, wildlife habitat, rodent use, insect infestations, fire, and other uses of the site should be recorded on the reverse side of the Site Information Sheet or on separate pages, as necessary.

Permanent Photopoints

Photographs can be a valuable information source and should be taken of all study areas. Photographs taken repeatedly at permanently marked locations can be an effective and efficient way to portray resource values and conditions. Photographs can be an important addition to each of the methods outlined below. Important considerations are: 1) identify the date and location within each picture; 2) take the picture during the same stage of plant growth each year; 3) include the same landscape and skyline in the picture each time one is taken; and 4) carefully relocate the photopoints each time a picture is taken.

Photographs that include a unique or distinctive landmark in the background or on the horizon are much easier to relocate. Photographs that are taken without a portion of the horizon in the picture make it difficult to locate the study site from a previously taken photograph. Photograph clarity and overall quality increases with higher resolution digital cameras and if the zoom feature is not used while taking the picture.

A single photograph from a permanently marked site (i.e., a fence post or large rock) can be effective at illustrating trends in resource condition of a study site, thereby providing an archived photograph of the site at that point in time. Include a Photo Information Sheet (see Appendix B) within each picture.

II. QUALITATIVE AND SEMI-QUANTITATIVE TECHNIQUES

Presence/absence

Brief Description

Presence/absence determines whether a species of interest (both desirable and undesirable) is found at a site. This method can be used to monitor the occurrence of a species of interest across the landscape. This method is especially applicable for species with many small populations.

Equipment

- Site Information Sheet
- Photo Information Sheet (optional)
- Notepad or data sheet to record any species located at the site
- Felt tip pen with waterproof ink
- Reference post and/or point (optional)

- Camera (optional)

Procedure

Determine if the method will be conducted by completing a drive-by or walk-through of the area where the plant species of interest occurs. Individuals with knowledge on correct identification of the plant of interest can be enlisted to perform this task while completing other work. Include a short form to document observer, date and time spent at site, whether it was a drive-by or walk-through, any issues or problems, and photographs that were taken of the site. It is recommended to develop a map of the entire resource area marking population areas discovered. A GPS unit can also be helpful in accurately documenting locations of plant species (and populations) of interest.

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet and Site Information Sheet.

Vegetation Attributes

- Species presence or absence

Estimation of population size

Brief Description

Visual evaluations of the size of a population of interest provide more information than simply determining presence or absence. These evaluations are often determined using classes to estimate number of individuals (such as 1–10, 11–100, 101–500, 501–1,000, etc.),

Equipment

- Site Information Sheet
- Photo Information Sheet (optional)
- Notepad or data sheet to record any species located at the site
- Felt tip pen with waterproof ink
- Compass
- Reference post and/or point (optional)
- GPS (optional)
- Camera (optional)

Procedure

If the population of cheatgrass is very large, or spread over a large area, consider using several marked macroplots where the number of plants or area is estimated. This should be small enough that an observer can view the entire macroplot from a single vantage point. Maintain the same observer, if possible. There may be variation in estimations if the same person does not continue recording size estimates during each site visit. If it is anticipated that more than one observer will record information, have the observers work together initially, if possible, so they can duplicate each other's methods down the road.

Consider using a permanent photopoint (see Section I), and note or map the location of the population or macroplot. Fill out and include Photo Information Sheet and Site Information Sheet.

Vegetation Attribute

- Population size

Weed mapping

Weed mapping includes depicting the perimeters of cheatgrass (or other weed) patches of interest. It is used to monitor change in the area occupied by the population. Some of the basic steps of cheatgrass mapping include:

- Defining the search area:
  - » The search area will likely be related directly to area of management "influence." An individual landowner may map his or her property, or work together with neighbors to cooperatively map a larger area if needed. An agency employee may map a particular allotment, a certain pasture, or a watershed. As the spatial extent of the search area increases, the level of effort also increases.
- Clarify the targeted mapping unit resolution:
  - » It is impractical to map each individual cheatgrass plant, even within a relatively small area. Some weed managers choose to map at the management-unit (pasture) level. If your management plan will only be implemented on a pasture-by-pasture basis, this may suit your needs; however, it will not present as clear a picture of cheatgrass distribution as other approaches. Cheatgrass is often very widespread and does not always occur in distinct patches, so a survey method may be an efficient way to map this species. Rather than a systematic search of every square foot in a management area, a series of points may be included within the long-term monitoring program to document cheatgrass distribution and severity.
- Determine the minimum separation between patches for them to be counted as separate patches.
  - » This is important when trying to characterize the nature of the population's spread across the landscape. If smaller patches are coalescing into larger patches, then management tactics to control cheatgrass may not be achieving intended results.
- Select the data collection or mapping type.
  - » There are many ways to gather spatial data about cheatgrass populations in the field. See the explanation below for a few commonly used methods.
- Determine how spatial data will be used for management actions.
  - » Once a clear picture of how cheatgrass is distributed across your management area, a landscape-scale management strategy can be devised and implemented. Areas that are cheatgrass free will be candidates for preventing introduction of cheatgrass onto the site. Small patches of cheatgrass in an area of high habitat value may be good candidates for local eradication. Employing the wildfire model of weed management (see Prioritization section, Chapter 3) depends largely on understanding the spatial distribution of cheatgrass within your management area.

Equipment

- Site Information Sheet
- Notepad or data sheet
- Felt tip pen with waterproof ink
- Compass
- Map (if a physical map is used)
- Markers for boundaries on map
- GPS

Procedure

There are four types of mapping commonly used today. Each is listed below in order from least to greatest accuracy.[4]

- The "paper-drawn polygon" method is a visual estimation of the species being monitored. The observer walks from the edge of the cheatgrass patch to the center to determine the size and shape of the patch. This size estimation is then recorded on the map.
- The "screen-drawn polygon" method uses computers or some type of GPS. The observer finds the edge or center of the cheatgrass patch being mapped and then calls up a topographic map of the area. The person then draws the estimated size of the patch onto the screen.
- The "buffered point" method can be very accurate even though it requires limited time to perform. The observer finds the center of the cheatgrass patch and records that point onto a GPS. Then you estimate the size or radius of the patch.
- The "perimeter-walked polygon" method provides the best mapping accuracy, but it may take the longest time to perform. This method requires the observer to walk around the cheatgrass patch, recording his or her GPS location every second. This gives you the closest estimation to the exact size and shape of the patch.

A fifth method may also be used. Aerial photography can cover large areas and be used to collect multiple photographs. These photographs can have different resolutions and spatial footprints, giving you a series of photographs to map out a given area. Aerial photographs can then be uploaded and used on a map to record what is present on the landscape. Depending on the time of year photographs are taken, cheatgrass can easily be seen using a low-level resolution aerial photograph. Remote sensing via satellites, aerial imagery, near-earth imagery, and other methods are beyond the scope of this handbook; however, your local natural resource professionals (Extension, NRCS, conservation districts, weed and pest control districts, etc.) can provide more information.

Consider setting up a permanent photopoint (see section I) within the area of interest. Fill out and include Photo Information Sheet and Site Information Sheet.

Vegetation Attribute

- Spatial distribution

Landscape Appearance Method

Brief Description

An ocular estimate is made of forage utilization based on the general appearance of the rangeland. Levels of utilization are determined based on the comparison of observations and written descriptions of each utilization class.

Training: A certain degree of subjectivity is involved in this method, as personal judgment is always a part of estimation. Keep in mind that estimates are only as good as the training and experience of the observers, who must be trained to recognize the seven utilization classes by the written descriptions of each class. Observers must think in terms of the general appearance of the site at each observation point, instead of weight or height of biomass removed.

Equipment

- Site Information Sheet
- Landscape Appearance Method form
- Camera and Photo Information Sheet (optional)
- Transect reference stake (optional)

Procedure

Permanently mark the study location, and consider establishing a permanent photopoint (see Section I) within the area of interest. Complete and include Photo and Site Information sheets.

Select a key or critical area and determine whether to use the herbaceous or browse species descriptions, and use the appropriate form (see Appendix B).

Choose a beginning point for a paced transect within the critical area. Ensure the transect remains within the same vegetation type (e.g., aspen-type, meadow-type, etc.). Establish a permanent photopoint looking down the transect, and include completed Photo Information Sheet.

Observe and record at least 25 samples per transect. Generally, a sample interval of 30 feet works fine for this method. Make certain the sample interval is recorded on the form.

Determine how many paces or steps will be taken to allow the selected sample interval, and begin pacing along the transect. When the predetermined number of paces or steps is reached, examine the immediate area in front of you and determine which landscape appearance class (see Appendix B) most accurately depicts the vegetation use.

Record findings as a dot tally in the appropriate row. It is helpful to visualize a 20-foot half-circle immediately in front of where you are standing. Often, you will increase accuracy of plant assessment when the plants are within about 20 feet of where you are standing.

After reaching the end of the transect, total the dots in each row and record them in the "count column." Then, multiply the count for each class by the midpoint displayed in the first column, and record the product. Calculate the average utilization by dividing the sum of products (B) by the total (A) count.

Vegetation Attribute

- Utilization
- Composition

Photopoints

Brief Description

These are photographs taken of the general view of the landscape from a permanent reference point. The photopoint location needs to be documented in writing, and the picture must include a reference point in the foreground (i.e., a fence post, fence line, or structure) and a distinct landmark on the skyline. Photopoints represent photographs that are retaken from the same position of the same scene at each observation.

Equipment

- Site Information Sheet
- Photo Information Sheet
- Notepad or data sheet
- Felt tip pen with waterproof ink
- Reference post and/or point
- Camera (the higher the resolution the better)

Procedure

Take photographs of a general view of the landscape (see Permanent Photographs, Section I). Consistently document the photopoint location for ease in revisiting the study site. Do this by placing the Photo Information Sheet in an upright position in the foreground of the scene that is being photographed.

To capture a general view of the landscape, stand at the selected point and include the Photo Information Sheet, a landscape view of the site, and some sky in the frame of the picture.

A picture of a study site taken from the closest road at the time the site is established may help facilitate relocation.

Repeat taking photographs at the same stage of plant growth, regardless of the date on the calendar.

It is a good idea to record field notes to supplement the photograph itself.

Vegetation Attribute

- Ocular estimate

- Frequency
- Structure
- Composition

Photoplots

Brief Description

Photoplots can determine site condition within a limited area from one year to the next. This technique can be valuable in providing a permanent record of the past, including aspects that may not have been considered at the onset of monitoring. Photoplots can also assist in documenting invasion by exotic or weedy species, successional changes, soil disturbance, and trampling of vegetation by livestock, wildlife (and people and their equipment). If using a reference post, consider placing the photoplot at least 20 feet away from the post.

Equipment

- Site Information Sheet
- Photo Information Sheet
- Frame to delineate the 3- by 3-foot photo plots (can be made from PVC pipe or similar material. A frame can also be formed using two carpenter rulers folded in half to make a square)
- Stakes of ¾- or 1-inch angle iron or PVC not less than 16 inches long
- Hammer
- Camera (the higher the resolution the better)
- Felt tip pen with waterproof ink
- Compass
- Reference post (steel post and driver) – optional
- Tarp (to block sun that may cause shadow effect) – optional. Using a tarp to shade the plot provides an even shade across the plot and reduces the contrast between full sun and shade beneath the vegetation canopy.

Procedure

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet.

Photoplots can be established randomly or permanently along a transect. Permanently establishing photoplots along a transect may assist in providing a more clear evaluation from year to year. Begin by completing the Site Information Sheet for the study site.

If using plots along a transect, first establish a transect (length of your choice; often 100 feet or 100 meters is used) and install permanent markers (see Permanently Marking the Study Location, above).

At the beginning of the transect (looking down the tape), take a landscape-oriented photograph.

Generally, a 3-foot square frame is used for photoplots; however, a different-sized frame can be used. Lay the frame over the transect tape so it intersects it at the 5-foot and 8-foot marks. Stand over the photoplot with toes touching the edge of the frame, and take a picture looking down at the frame with the 5-foot mark in the foreground and 8-foot mark in the background (using the zoom feature on the camera may decrease quality of photo).

Repeat the above process (with the frame), and take pictures at the 50-foot to 53-foot marks and again at 92-foot to 95-foot marks.

At the 100-foot mark at the end of the transect, take another photograph looking down the transect toward the 0-foot mark (beginning of transect).

In all photographs, the Photo Information Sheet should be visible. Using colored paper works better than white. With this method, five photographs will be taken.

Repeat taking photographs at the same stage of plant growth, regardless of the date on the calendar.

* If documenting trend and retaking photographs, use the same plot frame size as used in previous years.

* Pictures can be taken at various intervals along a transect as long as the procedure is consistent from year to year.

Vegetation Attribute

- Ocular estimate
- Frequency
- Composition

III. QUANTITATIVE TECHNIQUES

SamplePoint

Brief Description

The SamplePoint method is another form of point sampling to collect ground-cover measurements within an area of interest. SamplePoint differs in that photographs are taken along a transect and then analyzed using SamplePoint software. The software can be downloaded at no charge from the USDA–ARS SamplePoint.org website (http://www.samplepoint.org/).

Training: There is a learning curve involved with using the SamplePoint computer software program. However, only limited training is needed and once the user becomes familiar with the program, analysis of image data can be completed rapidly. For direct assistance with SamplePoint, contact your local Extension office. One important aspect of using SamplePoint is the camera used to take the photographs. Five- to 10-megapixel digital cameras are commonly used, but the greater the resolution the better. A higher resolution camera will take clearer images, making it easier to identify vegetation types as the photographs are analyzed with SamplePoint software. Take photographs at the highest resolution setting possible to improve clarity.

Equipment

- Site Information Sheet
- Photo Information Sheet
- Notepad or extra paper
- Plot labels (photo tags)
- Pencil or felt tip pen with waterproof ink
- Tape measure long enough to do desired measurable units
- Frame to delineate the 3x3-foot photo plots
- Stakes of ¾- or 1-inch angle iron or PVC not less than 16 inches long
- Hammer
- Compass
- Permanent marker (steel post and driver)
- Camera (the higher the resolution the better)
- Computer
- SamplePoint software (USDA–ARS)

Procedure

In the Field:

Locate key or critical areas when in the field (see Site Location, Section I). Fill out and include Site Information Sheet.

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet.

Run a transect tape out to desired length (usually 100 feet or 100 meters).

Take pictures looking down the transect and back up to get a general idea of the area and appearance of the plant community (include Photo Information Sheet in each picture). This also allows the observer to relocate the site in following years. Do not use the zoom-in feature on your camera for better quality photographs.

Make a complete list of all plant species (or be consistent in what you call each plant, and take a sample for identification purposes if necessary) in the vicinity of the transect to use as a reference while evaluating the photographs with SamplePoint. Keep the plant list with the Site Information Sheet to help ensure a correct record of the plants in each area monitored.

If using a 100-foot transect, place markers and take pictures at: 5’, 15’, 25’, 35’, 45’, 55’, 65’, 75’, 85’, and 95’ to provide a total of 10 pictures. Markers are placed 3 feet apart to form a 9-square-foot plot every 10 feet (5–8’, 15’–18’, etc.) beginning at the 5-foot mark on the tape (adjust according to length of transect and number of pictures desired).

Take a picture of each plot (you can move the camera closer to the ground to include just the markers in the picture to make the plot). It is important to have the correct angle when

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Figure A-2. An example of a photo identification tag used in each picture.

taking each picture. The lens of the camera should point directly toward the ground (a line from the camera to the ground is perpendicular). Place a photo identification tag in each picture (Fig. A-2). Try to place the tag in an area of bare soil so that you can properly identify that area as bare if a point falls on the tag during analysis. For photo tags, colored paper is easier to see than white paper once photos are loaded into the SamplePoint software program. The photo tag includes information regarding the date, observer, and the pasture or management unit in which the information is being recorded. The tag also records the image number along the transect. Beginning with the first plot (which will be 5'–8' on the tape) there will be no number marked out on the photo tag. For the next plot (15'–18'), the tag will have the number "5" marked out on it to signify that the first photograph has already been taken and you are at the 15-foot point on the transect tape. Continue the numbering process until all 10 photographs have been taken. Numbering aids in knowing which plot is which when the pictures are loaded into the SamplePoint program. Try hard not to forget the tags in all 10 plots!

At the Computer:

First, download the SamplePoint measurement software for free! This can be accessed at: http://www.samplepoint.org/

- Click on Download SamplePoint (this will take you further down the page)
- Fill in your name and email (this is only to keep track of who is visiting the site and to provide you any information, if necessary)
- Click on SamplePoint Install.exe to begin the installation process (this should only take a few minutes depending on Internet connection speed)
- The program should show up on your computer hard drive in the Programs folder (under SamplePoint)

Before proceeding, navigate to the location of your photographs. Determine which photographs are the "plots" to be evaluated with SamplePoint (close this window once photographs have been located).

- Optional: compile photographs (that will be used for SamplePoint) into one folder

Open SamplePoint. Under *Options*, click *Database Wizard – Create DB*

A new window will appear and request that you *Name the DataBase* – select a name that you will remember (writing the name in a notebook or computer file is advised) and that is representative of the area monitored (this name usually matches the name on data sheets in the landscape pictures [step #4 in the field]). Next, click *Create/Populate DataBase*.

Selecting the *Create/Populate DataBase* button brings up an *Open* window. Once in that window, navigate to where your plot photographs are located on the computer. Select all photographs that will be evaluated, and click *Open*. Select *Done* in the Create and Populate the DataBase window. Once you receive a message that the DataBase was successfully created, click *OK*.

Go to Options again, and click *Select DataBase* to access the DataBase you just created. This DataBase is a Microsoft Excel file. SamplePoint puts this file into the same folder containing the photographs you used to build the database.

The *Open* window will once again appear, and you must select the DataBase you have just created. Once it is found, Select the Excel file and click *Open*. A window will appear with the number of images to view (meaning the number of photographs you are going to evaluate). Make sure this is the correct number, and click *OK*.

Customizing Buttons

This first image is immediately brought up. At this point, you may want to customize the buttons for these pictures. To customize buttons, go to *Options*, select *Custom Buttons*, and arrow over to click *Create Custom Button Files*. This will bring up a Define Custom Buttons window. Write in desired buttons (species that are on your plant species list made in Create/Populate DataBase description in the field). You will have to re-write in the buttons that are originally provided by SamplePoint if you would like to keep those buttons. Click *Save* at the bottom of the window.

To load the buttons file you just created, click on *Options*, select *Custom Buttons*, and arrow over to select *Load Custom Button File*. Find the buttons file you just made, select it, and click *Open* (the buttons you created should show up on the bottom of the screen where the default buttons once were). This custom buttons file can be used in other databases as well.

SamplePoint defaults to 100 points per photograph; however, 25 points each on 10 photographs computes to 250 points per transect, which provides ample information. Thus, click on *Options* and go to *Select Grid Size*. Arrow over and select 5x5 = 25. Next, click *Begin* on the toolbar.

SamplePoint then projects 25 points arranged in a grid. The red crosshair is active while the yellow crosshairs depict other points that are not currently active or subject to classification. To change the color of the crosshair, click on *Options*, select *Change Crosshair Color*, and arrow over and select the desired color. A key component of the program is its ability to zoom in on a crosshair. To do this, change the number within the Zoom box located at the bottom left of the screen. After you have changed the number, click *Refresh*. Play around with the zoom feature to find what works best for you. The number below the zoom indicates what point you are on (1–25).

Once you have identified the plant in the crosshair, click on the correct button to identify the plant (bottom of screen). The exact location on the crosshair used for locating what to monitor is the very middle of the crosshair. SamplePoint will automatically go to the next crosshair on the grid.

Continue identifying each plant in the crosshair until you have gone through all 25 points. Once all points have been identified, a window will appear indicating that you have completed all the points. At this point, click *OK*, then *Next Image*, and then *Begin* (top of the toolbar).

Once you have gone through all images, a window will appear that states: "You have exhausted all the images!" Click *OK*.

Now, go to *Options* and select *Create Statistics Files*. Once the statistics file is created, a message will appear stating that the files were successfully created in (xx) seconds. A total of (xx) cells were processed. This is (an amount) msec per cell; press *OK*. At this point, Exit SamplePoint and Open your DataBase Summary (this will have the same name as your DataBase_summary.csv) to analyze and display the information you want.

The statistics file will be an Excel file with Key, Image, Comment, Grid Size, Actual Grass, and % Grass information included. If you would like to only view the actual number, you can delete the % columns. Conversely, you may want the % information and delete the actual columns. Either keep the percentage or the actual counts; it depends on personal preference which option is selected. Next, go to *File* and *Save As*. Save the file as an Excel workbook, preferably in the same folder as the pictures and buttons files. This way, every file pertaining to that sample date is in the same place.

Vegetation Attribute

- Cover
- Frequency
- Composition

Quadrats

Brief Description

Density of herbaceous plants is generally counted within the boundaries of a quadrat (each being a sampling unit). The size of the quadrat should not be too large regarding the number of individuals being counted or search time required. The size and shape of the quadrat must be tailored to the particular plant distribution observed and for most situations will be a rectangle. Quadrats can also be placed along a transect at predetermined intervals.

Density is often based on a count of plants that are rooted within a quadrat, but this works best if plants are distinct and with fairly small-diameter stems. Depending on the plant species, it can be difficult to determine whether a plant along the boundary is in or out of the quadrat. So, establishing whether a plant should be counted will need to be agreed upon and remain consistent among all observers.

Training: Observers will need to be able to correctly identify cheatgrass. There will need to be written guidelines on what constitutes the individual unit being counted (plants "in" versus plants "out" of the boundary).

Equipment

- Site Information Sheet
- Density Using Quadrats Form
- Quadrats (size appropriate for monitoring objective)
- Transect
- Two one-meter sticks (or yard sticks if using English measurements)
- Four stakes: ¾- or 1-inch angle iron or PVC pipe not less than 16 inches long
- Hammer
- Compass
- Camera and Photo Information Sheet (optional)
- Permanent marker (steel post and driver)

Procedure

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet and Site Information Sheet.

Site selection – Key or critical areas need to be selected. Study sites should be located within a single plant community within a single ecological site. Transects and sampling points need to be randomly located within the key or critical areas (see Site Selection).

Quadrat selection – Quadrats are a type of sampling unit within which data is actually collected. It is important to select the size and shape of the quadrate that will provide the highest statistical precision for the area and target species being sampled. Generally, long, thin quadrats are better than circles, squares, or shorter and wider quadrats.[5]

Monitoring location – Subjectively place quadrats in areas with large numbers of the target plant species, which is cheatgrass in this case.

Data collection – It is recommended that data be collected using the macroplot technique; belt transects are an easy way to collect density data for a particular plant species (see Belt Transect description below).

Vegetation Attribute

- Density
- Composition

Belt Transect (density measurement)

Brief Description

The belt transect can be briefly described as a larger macroplot that allows for a count to be determined for a plant of interest. It is useful to detect changes in plant species with low cover or density.

Training: It is important to train observers to identify all species (both desirable and undesirable) of interest or that could potentially invade a site, based on soil and climate characteristics.

Equipment

- Site Information Sheet
- Belt Transect form
- Tape measure for transect of desired length
- PVC pipe (at least ½ of belt transect width)
- Two stakes: ¾- or 1-inch angle iron or PVC pipe not less than 16 inches long
- Hammer
- Compass
- Camera and Photo Information Sheet (optional)
- Permanent marker (steel post and driver)

Procedure

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet and Site Information Sheet.

Select a study site that is agreed upon by vested interests.

Align a transect tape (100-foot, 200-foot, 100-meters, etc.) in a straight line, and stretch it between two permanent stakes.

With the PVC pipe held perpendicular to the transect, begin walking down the transect and count the number of plants of interest within the determined area (macroplot). This method works particularly well to determine density of shrubs or other prominent plants like invasive species.

Record the number of plants along the entire transect that are within the macroplot on the Belt Transect form (see Appendix B).

Vegetation Attribute

- Density
- Composition

Daubenmire method

Brief Description

The Daubenmire method is used to collect cover data and is based on a visual estimate of cover class.

Figure A-3. A simple way to make a Daubenmire frame for estimating cover is to use PVC pipe cut to the dimensions of 20 x 50 cm.

Equipment

- Site Information Sheet
- Daubenmire Cover form
- Pencil or felt tip pen with waterproof ink
- Daubenmire quadrat frame

Include if using Daubenmire with a line transect:

- Tape measure long enough to do desired measurable units.
- Stakes of ¾- or 1-inch angle iron or PVC not less than 16 inches long
- Hammer
- Compass
- Camera and Photo Information Sheet (optional)
- Permanent marker (steel post and driver)

Procedure

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet and Site Information Sheet.

Select a study site that is agreed upon by vested interests (see Study Site Location).

Align a tape (100-foot, 200-foot, 100-meters, etc.) in a straight line, and stretch it between two permanent stakes. Do not allow vegetation to deflect the alignment of the tape. Try and keep the tape as close to the ground as possible to increase accuracy.

Place the Daubenmire quadrat frame along the tape at specified intervals. Look at the quadrat frame from directly above and estimate the cover class for all individuals of a single plant species in the quadrat. Ignore all other kinds of plants, as each plant species is considered separately. Canopies extending over the quadrat are included even if the plants are not rooted in the quadrat (Fig. A-3).

It is ideal to conduct the Daubenmire method at a time of maximum growth of the species of interest.

Canopy cover that overlaps is included in the cover estimates by species. Therefore, total cover may exceed 100 percent. Total cover may not indicate actual ground cover.

Record data by quadrat, by species, and by cover class on the Daubenmire Cover form (see Appendix B).

Daubenmire Cover Classes:

Cover Class	**Range of Coverage**	**Midpoint of Range**
1	0–5%	2.5%
2	6–25%	15.0%
3	26–50%	37.5%
4	51–75%	62.5%
5	76–95%	85.0%
6	96–100%	97.5%

Vegetation Attribute

- Cover
- Frequency
- Composition

Point Intercept Method

Brief Description

The point intercept method measures cover based on observations made along a transect at specified intervals. At points along the transect, the observer uses a metal pin or wire to record the number of "hits", or times the pin made contact with the target species, out of the total number of points measured. Number of points placed on each transect is a question often asked. Fisser and VanDyne[6] found that sampling with fewer points and more transects was best when using the transect as the sampling unit. It is ideal to have enough points so that you intersect at least some individuals of the target species along each transect line.

Equipment

- Site Information Sheet
- Photo Information Sheet
- Point Intercept Method form
- Pencil or felt tip pen with waterproof ink
- Tape measure long enough for desired measurable units
- Long pin or pointer
- Stakes of ¾- or 1-inch angle iron or PVC not less than 16 inches long
- Hammer
- Compass

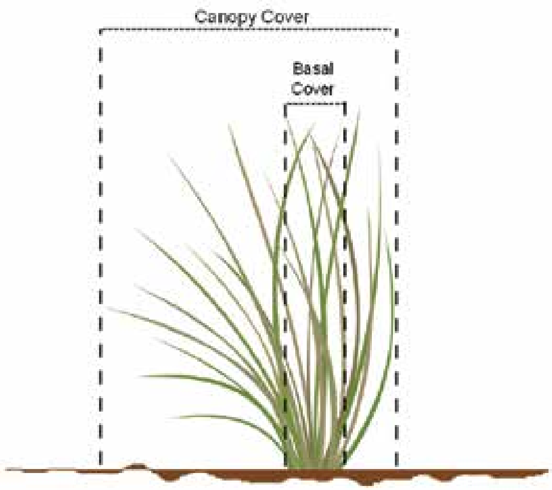

Figure A-4. Basal versus canopy cover. Basal cover is the area of ground surface covered by the base of a plant. Canopy cover is the ground surface covered by the plant when looking down on it from above.

- Permanent marker (steel post and driver)
- Camera

Procedure

Consider setting up a permanent photopoint (see Section I) within the area of interest. Fill out and include Photo Information Sheet and Site Information Sheet.

Begin by establishing a transect by tightly stretching a tape (100-foot, 200-foot, 100-meters, etc.) and install two transect stakes, one at the beginning and one at the end of the transect.

Take one photograph at the beginning of the transect (looking down the tape) and one at the end (looking back up the tape), and include a Photo Information Sheet in each photograph.

Before evaluating, decide if basal cover, canopy cover, or both will be documented. Basal cover is the area of ground surface covered by the base of a plant. Canopy cover is the ground surface covered by the plant when looking down on it from above. Both can be determined depending on goals and objectives (Fig. A-4).

Beginning at the specified location (often at one foot or one meter), lower a pin or wire pointer until initial contact is made with vegetation on the ground surface and record the data by dot count tally (explained in Appendix B), by category (life form), or by plant species in the appropriate section of the Point Intercept Method form. If there is a vegetation canopy layer, lower the pin through the vegetation until a basal or ground-level hit is made. This process is used to document basal cover.

To determine canopy cover, begin at the specified location and lower a wire pointer until initial contact is made with vegetation. Record the plant species with which contact was made by marking a dot count tally (or recording the number of hits) by category or plant species. Place a dot in the appropriate section on the Point Intercept Method form. If documenting both basal and canopy cover, record each plant species in the appropriate column and row (as canopy or basal).

Repeat this at each foot/meter-mark along the transect tape until the allotted number of points have been sampled.

Complete the Point Intercept Method form when all measurements are taken. The number of tallies in each column can be converted to the percent cover for each category or species (doing 100 points simplifies the conversion to percent cover).

Vegetation Attribute

- Cover
- Composition

Table A-1. Estimates of costs associated with various methods and amount of time it will take to conduct various monitoring methods (low, medium, and high).

Method	Approximate time to conduct	Cost
Photopoint	Low	Low
Landscape Appearance	Medium	Low
SamplePoint	Medium	Medium
Quadrats	High	Medium
Belt Transect	Medium	Low
Daubenmire	Medium	Medium
Point Intercept	High	Low

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Chris Evans, Illinois Wildlife Action Plan, Bugwood.org

Appendix B

Assessment and Monitoring Forms

PHOTO INFORMATION SHEET

Management Unit (Pasture, Allotment, etc.):

Location:

Study Site:

Observer(s):

Date:

Notes:

LANDSCAPE APPEARANCE METHOD (HERBACEOUS UTILIZATION)

Study Number: ______________________ Allotment/Pasture Name: ___________________________

Date: ______________________________ Transect Number and Location:______________________

Observer(s): _________________________ Animal Kind/Class:_______________________________

Season of Use:___________to _________ Sample Interval:_________________________________

Class (Midpoint)	(#) Count	# x Mid-point	Description of Landscape Appearance
0–5% (2.5%)			The rangeland shows evidence of no grazing, or of negligible use.
6–20% (13.0%)			The rangeland has the appearance of very light grazing. Herbaceous forage plants may be topped or slightly used. Few current seedstalks and young plants are grazed.
21–40% (30.5%)			The rangeland may be topped, skimmed, or grazed in patches. The low-value herbaceous plants are ungrazed, and 60–80% of the number of current seedstalks of herbaceous plants remain intact. Fewer than 50% of the young plants are grazed.
41–60% (50.5%)			The rangeland appears entirely covered as uniformly as natural features and facilities will allow; 15–25% of the number of current seedstalks of herbaceous species remain intact. No more than 10% of the low-value herbaceous forage plants have been utilized.
61–80% (70.5%)			The rangeland has the appearance of complete search. Herbaceous species are almost completely utilized, with less than 10% of the current seedstalks remaining. Shoots of rhizomatous grasses are missing. More than 10% of the low-value herbaceous forage plants have been utilized.
81–94% (87.5%)			The rangeland has a mown appearance, and there are indications of repeated coverage. There is no evidence of reproduction or current seedstalks of herbaceous species. Herbaceous forage species are completely utilized. The remaining stubble of preferred grasses is grazed to the soil surface.
95–100% (97.5%)			The rangeland appears to have been completely utilized. More than 50% of the low-value herbaceous plants have been utilized.

Totals	A=	B=

Average Utilization = B/A

SITE INFORMATION SHEET

Management Unit Name: ______________________ Date: ________

Study Site (# or name): ____________________ Study Location: ________________

Observer(s): ____

Monitoring Method(s) used: ____

Ownership (optional): ____

GPS Coordinates (optional): ____

Site Characteristics

Elevation (optional): _________ Soil type (optional): ______________________________

Avg. Annual Precipitation (optional): ____

% Slope and direction (optional): ____

Other Climatic Information (i.e., snow depth, temps., drought, etc. - optional):

Notes:

DENSITY USING QUADRATS

Study Site: ____________________	Date: ____________	Allotment/Pasture Name: ______________
Observer (s): ____		
Study Location : ____________________________		Quadrat Dimensions: Width______ Length ______
Notes:		

Plot	1	2	3	4	5	6	7	8	9	10	Total
Coordinates											
Plant Species											

BELT TRANSECT (MODIFIED)

Study Site: ____________________ Allotment/Pasture Name: ___________________

Observer (s): ______________________________________ Date: ________________

Study Location : ______________________________ Plot Dimensions: Width_______ Length _______

Density* = number of individuals per square meter or per square foot

Species	Tally Marks	Total	Density*

Unit for density = [ ] number per square foot

DAUBENMIRE COVER

Study Number: ____________ Date: _____________ Allotment/Pasture Name: ______________ Observer (s): __________________________________

Transect Number and Location: ____ Number of Plots: ______________________________

	Plot																								
Plant Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Cover classes: 1 (0-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), 5 (76-95%), 6 (96-100%)

POINT INTERCEPT METHOD

Study Number: ____________________________ Date: _____________ Allotment/Pasture Name: ______________________________

Transect Number and Location: ____

Observer (s): ____

Plant Species	Canopy	Basal	Percent Canopy Cover	Percent Basal Cover

SAMPLEPOINT METHOD PLOT LABELS (PHOTO TAGS)

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	

Ranch:	
Pasture:	
Date:	Transect:
Plot: 5 15 25 35 45 55 65 75 85 95	