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Cheatgrass: The Invader That Won the West

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Introduction

Cheatgrass: The Invader That Won the West

Cheatgrass (*Bromus tectorum*) is an introduced annual grass that is widely distributed on rangelands in the western U.S. The origins of cheatgrass are probably southwestern Asia (Young and others 1987) via contaminated grain from Europe in the late 1800s (Mack and Pyke 1983). Cheatgrass was preadapted to the climate and soils in the Great Basin Desert (parts of Idaho, Nevada, Oregon, and Utah) and filled a niche by the reduction of native herbaceous vegetation by historic fires.

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IDAHO STATE OFFICE**

1996

Cheatgrass is found in most of the western states having reached its range of current distribution by 1930 (Black 1981). Hall (1965) reported that a survey of 11 western states showed that cheatgrass was present on at least 80 million acres. In a more recent survey, Pellant and Hall (1994) found 3.3 million acres of public lands in the Great Basin Desert dominated by cheatgrass and another 76.1 million acres either infested with or susceptible to cheatgrass invasion. The spread of cheatgrass could increase in the future due to its ability to evolve to survive in new environments and presence of multiple genotypes (Novak 1994).

INTERIOR COLUMBIA BASIN ECOSYSTEM MANAGEMENT PROJECT

The art and science of ecosystem management is advancing. However the words of Aldo Leopold (1949) in his classic, "A Sand County Almanac," are still true for ecologists. "I looked carefully for clues whether the West has accepted cheat as a necessary evil, to be tolerated with unshaken calm, or whether it regards cheat as a challenge that must be met. I found the hopeless attitude almost universal."

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Introduction

Cheatgrass (*Bromus tectorum*) is an introduced annual grass that is widely distributed on rangelands in the western U.S. The origins of cheatgrass are probably southwestern Asia (Young and others 1987) via contaminated grain from Europe in the late 1890's (Mack and Pyke 1983). Cheatgrass was preadapted to the climate and soils in the Great Basin Desert (parts of Idaho, Nevada, Oregon, and Utah) and filled the void left vacant by the reduction of native herbaceous vegetation by historic livestock grazing (Young and others 1987). This opportunistic grass is able to maintain a superiority over native plants in part because it is a prolific seed producer (Hulbert 1955), able to germinate in the autumn or spring giving it a competitive advantage over native perennials (Martens and others 1994) and is tolerant of grazing and increases with frequent fire (Klemmedson and Smith 1964).

Cheatgrass is found in most of the western states having reached its range of current distribution by 1930 (Mack 1981). Hull (1965) reported that a survey of 11 western states showed that cheatgrass was present on at least 60 million acres. In a more recent survey, Pellant and Hall (1994) found 3.3 million acres of public lands in the Great Basin Desert dominated by cheatgrass and another 76.1 million acres either infested with or susceptible to cheatgrass invasion. The spread of cheatgrass could increase in the future due to its ability to evolve to survive in new environments and presence of multiple genotypes (Novak 1994).

The art and science of managing or restoring cheatgrass rangelands is advancing. However the prophetic words of Aldo Leopold (1949) in his classic, "A Sand County Almanac" are still cause for thought, "*I listened carefully for clues whether the West has accepted cheat as a necessary evil, to be lived with until kingdom come, or whether it regards cheat as a challenge to rectify its past errors in land-use. I found the hopeless attitude almost universal*".

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The remainder of this manuscript will describe the ecology of cheatgrass and management options to maintain or restore ecologically functioning rangelands. The emphasis will be on strategies to reduce impacts of cheatgrass on ecological, resource and economic values in the Great Basin and Columbia River Basins. This review will focus on the proceedings of a 1992 symposium on the, "Ecology, Management and Restoration of Intermountain Annual Rangelands" held in Boise, Idaho (Monsen and Kitchen 1994).

Ecology

Cheatgrass is a winter annual that germinates in the fall, if climatic conditions are favorable, or in the following spring insuring annual recruitment (Mack and Pyke 1983). Fall germination and rapid elongation of roots provides cheatgrass with a competitive advantage over native perennial species (Harris 1967). Aguirre and Johnson (1991) reported that cheatgrass reduced growth of seedlings of hybrid crested wheatgrass (*Agropyron cristatum X A. desertorum*) and bluebunch wheatgrass (*Pseudoroegneria spicata*). They also reported that cheatgrass is capable of producing twice the quantity of roots as bluebunch wheatgrass during the first 45 days of growth.

The prolific seed production of cheatgrass also contributes to the competitive advantage of this grass over native vegetation (Hulbert 1955). Stewart and Hull (1949) reported an average seed production of 478 pounds per acre on cheatgrass range near Boise, Idaho.

Young and others (1969) and Young and Evans (1975) determined that cheatgrass in degraded big sagebrush (*Artemisia tridentata*) communities in Nevada produces between 5,000 to 15,000 seeds per m² while even higher seed densities (17,717/m²) were reported in Idaho (Stewart and Hull, 1949). Cheatgrass can also survive periodic drought because viable seeds survive in the soil for up to 5 years (Young and others 1969).

Plant densities of cheatgrass in degraded sagebrush ecosystems range from 10-13,000 plants per m² in Nevada (Young and others 1969) to 6,500 plants per m² in Idaho (Hull and Pehanec 1947). Given the high plant densities and seed production of this exotic grass, it is not surprising that cheatgrass can invade and dominate disturbed rangelands.

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The remainder of this manuscript will describe the ecology of cheatgrass and management options to maintain or restore ecologically functioning rangelands. The emphasis will be on strategies to reduce aspects of cheatgrass on ecological, economic and social values in the Great Basin and Columbia River Basin. This review will focus on the proceedings of a 1992 symposium on the "Ecology, Management and Restoration of Intermountain Annual Rangelands" held in Boise, Idaho (Mooney and Kitchen 1994).

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Plant densities of cheatgrass in degraded sagebrush ecosystems range from 10-13,000 plants per m² in Nevada (Young and others 1989) to 6,300 plants per m² in Idaho (Hall and Peltzer 1977). Given the high plant densities and seed production of this exotic grass, it is not surprising that cheatgrass can invade and dominate disturbed rangelands.

The life cycle of cheatgrass also contributes to its competitive advantage over native

herbaceous plants. Cheatgrass can germinate in the fall or spring (Mack and Pyke 1983). Cheatgrass can out compete natives for water and nutrients in the early spring since cheatgrass is actively growing when many natives are initiating growth. Cheatgrass also completes its reproductive process and becomes senescent before most native plants. As a result cheatgrass does not efficiently utilize the sun's energy throughout the growing season reducing the efficiency of energy flow in cheatgrass dominated communities. In comparison, most native plant communities contain a sufficient assemblage of plants to insure that photosynthesis is occurring throughout the growing season.

The short growth period of cheatgrass relative to native plants also increases the likelihood of wildfire starts and spread (Pellant 1990). Platt and Jackman (1946) reported that cheatgrass became flammable 4-6 weeks earlier and remained susceptible to wildfires 1-2 months later than native perennials. Cheatgrass is usually dry by mid-July whereas perennial plants can still contain 65 per cent moisture on the same date (Murray and others 1978).

Standing dead cheatgrass and litter are extremely flammable resulting in a shorter wildfire return interval now compared to just prior to European mans arrival in the Intermountain west (Billings 1948). Historically, wildfires occurred at return intervals of 32-70 years in sagebrush types in the Great Basin (Wright and others 1979). Wildfire return intervals are now less than 5 years on certain southern Idaho rangelands heavily infested with cheatgrass (Pellant 1990). As a result native plant diversity is reduced and recovery periods are longer on burned rangelands (Whisenant 1990). Billings (1994) warns that some native plants and animals in western ecosystems prone to wildfires are in danger extinction.

Young and others (1987) describe the "phenotypic plasticity" as another advantage cheatgrass has over perennial plants. After a wildfire the normally self-pollinating cheatgrass plants are more likely to cross-pollinate filling the environment with cheatgrass plants exhibiting hybrid vigor. Vigorous cheatgrass plants are better adapted to efficiently utilize nutrients and soil water than native plants after a wildfire.

Cheatgrass is adapted to many biotic regimes from low elevation salt desert shrub communities (Sparks and others 1990; Young and Tipton 1990) to the higher elevation ponderosa pine zone (Daubenmire 1952). These communities range from 1,500 to 9,000 ft in elevation and

from 6 to over 20 inches of average annual precipitation. The biotic communities most at risk to the impacts of the "cheatgrass-wildfire cycle" are the Wyoming big sagebrush and more mesic salt desert shrub plant communities (Peters and Bunting 1994; Pellant 1990). Not only is cheatgrass adapting to new environments, it is now being invaded by other noxious weeds. Larsen and Sheley (1994) report that yellowstar thistle (*Centaurea solstitialis*) is now a codominant with cheatgrass on some northern Great Basin rangelands.

Cheatgrass also modifies the ecosystem attributes of soil temperature and soil water distribution. Soil temperature outside big sagebrush canopies is 10°C warmer than the soil temperature in the interspaces between shrubs (Wight and others 1979). Therefore, conversion of sagebrush steppe to cheatgrass rangeland may result in a warmer microclimate in "shrubless" areas.

Cheatgrass is also an efficient user of soil water in the upper soil profile. Cline and others (1977) reported that a cheatgrass community was more efficient at using water to a soil depth of 0.5 m than was a native bluebunch wheatgrass community. However, the bluebunch community extracted water deeper in the soil profile. Soil water extraction can also be related to the rooting depth of plants. The difference in rooting depth between native plants and cheatgrass was investigated by Spence (1937) in southern Idaho. He found that cheatgrass produced an average of 7 roots per plant that penetrated an average of 30 cm. In contrast, bluebunch wheatgrass averaged 176 roots per plant that penetrated 105 cm into the soil profile.

These studies indicate that conversion of shrub steppe rangeland to annual grasslands could result in large acreages of rangeland with warmer soil temperatures and an unequal distribution of soil water with the upper soil profile depleted of water sooner by cheatgrass and the water in the deeper soil profile not efficiently utilized.

The availability and uptake of nutrients is also impacted by cheatgrass. The high nitrogen use efficiency of cheatgrass gives it a competitive advantage over associated annual forbs (McLendon and Redente 1992) and some perennial plants (Link and others 1990). McLendon and Redente (1992) suggest that the incorporation of large amounts of available nitrogen in the biomass of annual species and subsequent slow rate of decomposition eventually results in an equilibrium allowing reestablishment of perennial vegetation. However, cheatgrass has the

from 6 to over 20 inches of average annual precipitation. The plant communities most at risk to the impact of the "cheatgrass-wildfire cycle" are the *H. patens* big sagebrush and more mesic soil desert shrub plant communities (Peters and Bunting 1994; Felton 1990). Not only is cheatgrass replacing in new communities, it is now being invaded by other noxious weeds. Larson and Shiley (1994) report that yellow star thistle (*Centaurea solstitialis*) is now a

component of the cheatgrass on some northern Great Basin rangelands. Cheatgrass also modifies the ecological attributes of soil temperature and soil water distribution. Soil temperature outside big sagebrush canopies is 10°C warmer than the soil temperature in the interspaces between shrubs (Wright and others 1979). Therefore, conversion of sagebrush to cheatgrass rangelands may result in a warmer microclimate to "shrubs".

Cheatgrass is also an efficient user of soil water in the upper soil profile. Chao and others (1977) reported that a cheatgrass community was more efficient at using water to a soil depth of 0.5 m than was a native blackbrush community. However, the blackbrush community extracted water deeper in the soil profile. Soil water extraction can also be related to the rooting depth of plants. The difference in rooting depth between native plants and cheatgrass was

investigated by Specht (1977) in southern Idaho. He found that cheatgrass produced an average of 1 root per plant that penetrated an average of 30 cm. In contrast, blackbrush wheatgrass averaged 1.75 roots per plant that penetrated 105 cm into the soil profile. These studies indicate that conversion of shrub steppe rangelands to annual grasslands

would result in large savings of water with warmer soil temperatures and an upward distribution of soil water with the upper soil profile depleted of water sooner by cheatgrass and the water in the deeper soil profile not efficiently utilized.

The availability and uptake of nutrients is also impacted by cheatgrass. The high nitrogen use efficiency of cheatgrass gives it a competitive advantage over associated annual forbs (McCandon and Redman 1992) and other perennial plants (Link and others 1990). McCandon and Redman (1992) suggest that the incorporation of large amounts of available nitrogen in the biomass of annual forbs and subsequent slow rate of decomposition eventually results in an equilibrium showing establishment of perennial vegetation. However, cheatgrass has the

potential for long term site dominance since it has a low nitrogen requirement and early, rapid growth.

Cheatgrass is especially competitive with perennial plants after a wildfire when additional nitrogen is released by the burning of standing biomass and litter.

Net primary production of cheatgrass varies considerably from year to year. Although cheatgrass has a short growing season it can produce more biomass in some years than native vegetation and seeded wheatgrasses (Hull and Pehanec 1947). They found a tenfold difference in cheatgrass production between a wet and dry year (3,461 and 361 lbs/ac, respectively), while an introduced wheatgrass seeding produced 2,472 and 1,285 lbs/ac during the same wet and dry years. In Washington, Rickard and others (1988) reported that aboveground biomass production was similar between a sagebrush-bunchgrass community (426gm/m²) and a cheatgrass community (465 g/m²). However, nearly 25% of the aboveground biomass produced in the sagebrush community was tied up in live or dead woody tissue.

Cheatgrass normally provides adequate cover for watershed protection. Stewart and Hull (1949) reported that cheatgrass litter effectively reduces raindrop energy and promotes infiltration. However in drought years and after a wildfire this protection is reduced and the potential for erosion is increased. The advantages of cheatgrass for site protection can be offset by the uncertainty of its presence especially on sites with erodible soils and moderate to steep slopes.

The relationship between cheatgrass and microbiotic crust (composed of lichens, mosses, algae and liverworts) in the Great Basin is not well understood. Pellant and Kaltenecker (1996) reported a reduction in diversity and cover of microbiotic crusts on cheatgrass infested rangeland in southwestern Idaho compared to native sagebrush steppe. Cheatgrass is able to quickly dominate burned sites thereby hindering the recovery of microbiotic crust species. The reduction in the diversity and cover of microbiotic crusts may disrupt the ecological processes of the nutrient and hydrologic cycle and energy flow as well as site stability and resistance to entry of undesirable weeds such as cheatgrass.

In summary the introduction of cheatgrass into the Great Basin and Upper Columbia River Basin has upset the ecological "apple cart". Ecological processes such as energy flow, nutrient

potential for long term site dominance since it has a low nitrogen requirement and early rapid growth.

Chestnut is very competitive with perennial plants after a wildfire when additional nitrogen is released by the burning of standing biomass and litter.

The primary production of chestnut varies considerably from year to year. Although chestnut has a short growing season it can produce more biomass in some years than native vegetation and woody shrubs (Hall and Petrone 1947). They found a marked difference in chestnut production between a wet and dry year (3,461 and 1,061 lbs/ac, respectively), while an introduced chestnut seedling produced 2,472 and 1,585 lbs/ac during the same wet and dry years. In Washington, Richard and others (1988) reported that aboveground biomass production was similar between a sagebrush-bunchgrass community (4,500 g/m²) and a chestnut community (4,400 g/m²). However, nearly 22% of the aboveground biomass produced in the sagebrush community was dead up in live or dead woody stems.

Chestnut normally provides adequate cover for watershed protection. Stewart and Hall (1949) reported that chestnut litter effectively reduces rainfall erosion and promotes infiltration. However, in drought years and after a wildfire this protection is reduced and the potential for erosion is increased. The advantages of chestnut for site protection can be offset by the mortality of its presence especially on sites with erodible soils and moderate to steep slopes.

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In summary the introduction of chestnut into the Great Basin and Upper Columbia River Basin has upset the ecological "apple cart". Ecological processes such as energy flow, nutrient

and hydrologic cycle and the structure and dynamics of the areas fauna and flora have been adversely affected and in some instances disrupted by cheatgrass invasion and dominance. In addition to the ecological implications associated with cheatgrass invasion, the impacts to land uses in the area are also significant.

Impacts of Cheatgrass on Land Uses

Since cheatgrass was introduced into the Great Basin it has been either a curse or blessing depending on which land use one valued the most. Cheatgrass has certainly had a positive impact on the livestock industry of the region. Hull and Pechanec (1947) stated that cheatgrass was the most important forage plant in Idaho providing more than half of the forage on spring ranges in the southern part of the state. Cheatgrass probably provides more forage for livestock in Nevada than any other species (Swanson and others 1987). As discussed earlier, annual forage production of cheatgrass is highly variable (Stewart and Young 1939; Klemmedson and Smith 1964,) requiring variable livestock stocking rates. Carrying capacities for cheatgrass dominated rangelands have been estimated at 1.5 to 3.0 acres per Animal Unit Month (AUM) on "good" cheatgrass range (Hull and Pehanec 1947) to 5-8 acres per AUM on other Idaho rangelands (Klemmedson and Smith 1964).

Forage quality and digestibility also affect cheatgrass use by livestock. The period that cheatgrass is palatable and nutritious for herbivore consumption is considerably shorter than for most native herbaceous plants (Klemmedson and Smith 1964). Forage quality declines as cheatgrass matures, therefore early spring to early summer grazing provides the greatest nutritional benefits to livestock (Murray and others 1978).

Cattle may continue to utilize cheatgrass after it is dry if adequate water is present or the cheatgrass is softened by rain (Hull and Pehanac 1947). DeFlon (1986) recommends the use of cheatgrass for winter grazing by cattle. He states that cheatgrass use in the spring is detrimental to stand maintenance whereas winter grazing reduces the need for costly livestock feeding programs and maintains a good stand of cheatgrass. Another rancher in Nevada (Tipton 1994) extolls the value of cheatgrass rangeland for winter livestock use and adds a side benefit of fuels reduction for wildfire control.

Cheatgrass has also increased the extent and frequency of rangeland wildfires in the Great Basin and Upper Columbia River Basin with significant impacts to natural and fiscal resources (Billings 1994, Pellant 1990). Both wildfire suppression and rehabilitation costs have risen as the number and size of wildfires have increased (Roberts 1990). The loss of private structures on the urban-wildland interface is also increasing as a result of the increased incidence of wildfire starts in exotic annual grasses (Nevada Association of Counties Natural Resources Report 1988). The protection of life and private property is the top priority of public land agency firefighters. This policy hinders the protection of public land resource values and will be even more of a problem in the future as additional housing is constructed on the urban-wildland interface.

The increase in wildfires in the Great Basin has resulted in loss of important big game winter ranges in the Great Basin (Pellant 1990; Updike and others 1990), habitat supporting North America's densest concentration of nesting raptors (Kochert and Pellant 1986), native sensitive plant species (Rosentreter 1994) and nongame bird occurrence (Dobler 1994). In addition, plant diversity is reduced at both the local and landscape levels with frequent wildfires (Whisenant 1990).

The *cheatgrass-wildfire cycle* has indirectly resulted in additional loss of native plant diversity as a result of the common practice of planting introduced wheatgrasses, primarily crested wheatgrass (*Agropyron cristatum*), after wildfires. The use of seed mixtures composed primarily of crested wheatgrass to exclude cheatgrass after wildfires and provide livestock forage was a common practice in the 1950-70's and continues to a certain extent today (Pellant and Monsen 1993). The end result of this practice was to reduce monocultures of cheatgrass on the landscape by establishing monoculture plantings of crested wheatgrass. Crested wheatgrass was seen as the lesser of two evils because it is a perennial bunchgrass that resists burning and provides a better quality and more dependable forage for livestock and some wildlife species when compared to cheatgrass. The debate continues today as to the merits of using an exotic perennial grass to preclude the establishment of an exotic annual grass.

Management Strategies for Cheatgrass Rangelands

Chesnut has also reviewed the extent and frequency of rangeland wildfires in the Great Basin and Upper Columbia River Basin with significant impacts on natural and social resources (Billings 1994, Pellatt 1999). Both wildfire suppression and rehabilitation costs have risen as the number and size of wildfires have increased (Roberts 1990). The loss of private structures on the urban-wildland interface is also increasing as a result of the increased incidence of wildfire starts in exotic rangelands (Nevada Association of Counties Natural Resources Report 1988). The protection of life and property is the top priority of public land agency managers. This policy hinders the protection of public land resource values and will be even more of a problem in the future as additional housing is constructed on the urban-wildland interface.

The increase in wildfires in the Great Basin has resulted in loss of important bird species where rangelands in the Great Basin (Pellatt 1999, Tjebk and others 1990) habitat supporting North America's greatest concentration of nesting raptors (Lockert and Pellatt 1988), native sensitive plant species (Rosenstock 1994) and sagebrush and oak woodlands (Dobler 1994). In addition, plant diversity is reduced at both the local and landscape levels with frequent wildfires (Pellatt 1999).

The chesnut-wildfire cycle has indirectly resulted in additional loss of native plant diversity as a result of the common practice of planting introduced weeds, primarily created by agriculture (agriculture resistant) after wildfires. The use of seed mixtures composed primarily of exotic wheatgrass to exclude chesnuts after wildfires and provide livestock forage was a common practice in the 1950-70's and continues to a certain extent today (Pellatt and Monson 1995). The end result of this practice was to reduce concentrations of chesnuts on the landscape by establishing monoculture plantings of exotic wheatgrass. Exotic wheatgrass was seen as the least of two evils because it is a perennial bunchgrass that resists burning and provides a better quality and more dependable forage for livestock and some wildlife species when compared to chesnuts. The debate continues today as to the merits of using an exotic perennial grass to exclude the establishment of an exotic annual grass.

Management Strategies for Chesnut Rangelands

A variety of rehabilitation techniques have been developed to establish perennial (native or introduced plant species) to reduce cheatgrass expansion. Management strategies, primarily livestock grazing systems, can also be used to reduce the cheatgrass fire hazard. All management prescriptions to reduce cheatgrass must be evaluated with an understanding of state and transition models (Westoby and others 1989) and the concept of rangeland thresholds (Friedel 1991).

Thresholds

A major question in the management of cheatgrass infested rangelands is can livestock grazing management practices can be used to improve the vigor and quantity of native perennial vegetation by reducing the competition of cheatgrass. If livestock management is not effective in meeting this objective, rehabilitation (includes the use of some non-native species) or restoration (native species only) are viable yet expensive alternatives to reestablish perennial plants.

The selection of treatments to restore perennial vegetation in cheatgrass infested rangelands is largely dependent on the degree of cheatgrass dominance.

Recently new explanations have been proposed to address plant communities that do not respond to traditional management practices. The concept of a threshold of environmental change has been proposed by Friedel (1991) to explain situations where shifts in plant community composition or structure are drastic and the possibility of a return to the original plant community by simply changing livestock grazing management is unlikely. Westoby and others (1989) described discrete, stable states of vegetation that change only when major disturbances cause a shift from one stable state to another.

Most recently the National Research Council (NRC 1994) proposed the concept of rangeland health as a common denominator for the description of the nation's rangelands. They defined rangeland health as, "*the degree to which the integrity of the soil and ecological processes of rangeland ecosystems are sustained.*" Ecological processes include the water and nutrient cycle and energy flow. Applying the concepts of rangeland health and thresholds to cheatgrass infested rangelands would yield valuable information for science based management decisions. Unfortunately, little research has been done to identify the thresholds of cheatgrass dominance whereby a disruption in ecological processes, native plant composition or soil

A variety of rehabilitation techniques have been developed to establish perennial forage or introduced plant species to reduce chevron expansion. Management strategies primarily livestock grazing systems can also be used to reduce the chevron. The latter. All management prescriptions to reduce chevrons must be evaluated with an understanding of soil and transition models (Wentworth and others 1988) and the concept of threshold thresholds (Tillett 1991).

Thresholds

A major question in the management of chevron is whether introduced forage or livestock grazing management practices can be used to improve the vigor and density of native perennial vegetation by reducing the competition of chevrons. If livestock management is not effective in reducing the chevron, rehabilitation (includes the use of native non-native species) or transition (native species only) are viable yet expensive alternatives to establish perennial plants. The selection of species to restore perennial vegetation in chevrons is related to vegetation is largely dependent on the degree of chevron dominance.

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Also recently the National Research Council (NRC 1994) proposed the concept of threshold health as a constant characteristic for the description of the nation's rangelands. They defined threshold health as "the degree to which the integrity of the soil and ecological processes of rangeland is constant and sustained." Ecological processes include the water and nutrient cycle and energy flow. Applying the concepts of threshold health and thresholds to chevron infested rangelands would yield valuable information for rangeland based management decisions. Unfortunately, little research has been done to identify the thresholds of chevrons dominance relative to a disruption in ecological processes, native plant competition or soil

instability occurs.

Some research and publications have addressed the role of cheatgrass in rangeland health and the topic of thresholds. Laycock (1991) cited southern Idaho cheatgrass communities as examples of a wildfire maintained steady state that would not return to the original native vegetation with livestock removal. Young and Evans (1978) speculated that removal of livestock would actually accelerate conversion to cheatgrass because of increased fuel accumulations and more frequent wildfires.

An acceptable ratio of cheatgrass to native plants i.e. a threshold whereby ecological processes are still functioning has not been identified. This threshold would vary by ecological site, climatic conditions, management, and disturbance regime. One approach to identify this threshold is to review past rehabilitation research that describes the competitive interactions of seeded plants and cheatgrass. This relationship between density of cheatgrass and perennial plant establishment could provide an insight into acceptable levels of cheatgrass in native communities.

Evans (1961) reported that cheatgrass densities of 689 and 2,756 plants/m² greatly reduced growth and survival of crested wheatgrass seedlings. Even cheatgrass densities of 43-172 plants/m² negatively affected establishment of seedlings of crested wheatgrass. Native grasses generally have poorer seedling vigor than the introduced grasses therefore native plant recruitment could be negatively affected by cheatgrass densities of 50 or more plants/m².

Evans and Young (1977) considered 3 crested wheatgrass plants per m² to be an acceptable density to maintain perennial vegetation in low elevation sagebrush rangelands.

Useful information on cheatgrass thresholds can also be derived from ecological studies. Hulbert (1955) found cheatgrass in lightly disturbed native vegetation stands in the Pacific Northwest. These cheatgrass plants were small and produced very little seed. Cheatgrass is a component of isolated kipukas of ungrazed native vegetation in lava flows in southeastern Oregon (Kindschy 1994) and on an ungrazed island in Pyramid Lake, Nevada (Tausch and others 1994). In fact, this island has been isolated from human disturbance for nearly 80 years yet cheatgrass is still the dominant species on 35 per cent of this 90 ha island. These studies demonstrate the competitive ability of cheatgrass allowing it to invade and sometimes dominate native plant communities protected from disturbance from man and domestic livestock.

Some research and publications have addressed the role of cheaters in riparian beds and the type of thresholds. Lauenroth (1981) cited southern Idaho cheaters communities as

examples of a system maintained steady state that would not return to the original state vegetation with livestock removal. Young and Evans (1978) speculated that removal of livestock

would actually accelerate conversion to cheaters because of increased fuel accumulation and more frequent wildfires.

An acceptable ratio of cheaters to native grass is a threshold whereby ecological processes are still functioning but have been identified. This threshold would vary by ecological

site, climate conditions, management, and disturbance regime. One approach to identify this threshold is to review past vegetation research that describes the competitive interactions of

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Evans (1961) reported that cheaters densities of 68% and 2,756 plants/m² greatly reduced growth and survival of seeded wheats and barley. Even cheaters densities of 43-

173 plants/m² negatively affected establishment of seeded wheats and barley. Native grasses generally have greater seedling vigor than the introduced grasses therefore native plant

recruitment could be negatively affected by cheaters densities of 50 or more plants/m². Evans and Young (1977) considered 3 annual wheats plants per m² to be an acceptable

density to maintain perennial vegetation in low elevation sagebrush rangelands. Similar information on cheaters thresholds can also be derived from ecological studies

Hunter (1983) found cheaters in light-thinned native vegetation stands in the Pacific Northwest. These cheaters plants were small and produced very little seed. Cheaters as a

component of seeded riparian of riparian native vegetation in low flows in southeastern Oregon (Kiloby 1981) and on an upland island in Pyramid Lake, Nevada (Teach and others 1984).

In fact, this island has been isolated from human disturbance for nearly 50 years yet cheaters is still the dominant species on 35 per cent of the 98 ha island. These studies demonstrate the

competitive ability of cheaters allowing it to invade and sometimes dominate native plant communities protected from disturbance from man and domestic livestock.

Evans and Young (1995) determined that **native** perennial plant densities of 2.5 plants per m^2 were adequate to prevent cheatgrass dominance if the shrub portion of a shrub steppe community was removed. This perennial plant density is probably inadequate if the native plants are young or if the plants are relatively small i.e. Sandberg bluegrass (*Poa sandbergii*). Another limitation with using set perennial plant densities as a threshold of rangeland health include the spatial and temporal variability of plant communities and the interaction of microbiotic crusts and perennial plants in excluding cheatgrass.

Therefore, cheatgrass is and will remain a component of rangeland ecosystems throughout the Intermountain area (Young and others 1972). No research has been conducted regarding the threshold of cheatgrass dominance necessary to preempt the proper functioning of ecological processes. Managers should be concerned about cheatgrass invasion when perennial shrubs/forbs and larger native grasses number less than 3 plants per m^2 and cheatgrass is known to be adapted to the ecological site.

Restoration of Perennial Plants in Cheatgrass Communities

If sufficient native plants are present and cheatgrass densities are not above an unacceptable threshold, livestock grazing management practices can be used to restore the native plant community. If the cheatgrass threshold is crossed, intervention through artificial reseeding may be the only recourse to obtain satisfactory native or introduced plant communities. Site preparation to control cheatgrass competition is essential, especially in the more arid rangeland systems, prior to reseeding adapted plants (Jordan 1983). Afterwards, proper grazing management is required after revegetation to maintain the seeded plants.

Cheatgrass Control Prior to Reseeding

It is well established that cheatgrass must be effectively controlled prior to attempts to revegetate cheatgrass infested rangelands (Hull and Stewart 1948; Evans and Young 1977; Jordan 1983).

A variety of techniques including mechanical (disking or plowing), burning, grazing and herbicide treatments have been employed to reduce cheatgrass competition prior to seeding. These treatments vary in their effectiveness according to cheatgrass phenology, pre- and post-

Evans and Young (1977) determined that native perennial plant densities of 2.2 plants per m² were adequate to prevent chestruss dominance if the shrub portion of a shrub steppe community was removed. This perennial plant density is probably inadequate if the native plants are young or if the plants are relatively small, i.e. seedling chestruss (Evans and Young 1977). Another limitation with using a perennial plant density as a threshold of rangeland health include the spatial and temporal variability of plant communities and the interaction of microbial stress and perennial plant in reducing chestruss.

Therefore, chestruss is and will remain a component of rangeland ecosystems throughout the western United States (Young and others 1973). No research has been conducted regarding the threshold of chestruss dominance necessary to prevent the proper functioning of ecological processes. Managers should be concerned about chestruss invasion when perennial plant/soil and water nutrient levels are lower than 3 plants per m² and chestruss is known to be adapted to the ecological site.

Restoration of Perennial Plants in Chestruss Communities

If sufficient native plants are present and chestruss densities are not above an acceptable threshold, livestock grazing management practices can be used to restore the native plant community. If the chestruss threshold is crossed, intervention through artificial seeding may be the only means to obtain satisfactory native or introduced plant communities. Site preparation to control chestruss competition is essential, especially in the more arid rangeland systems prior to seeding selected plants (Jordan 1983). Afterwards, proper grazing management is required until rangeland is restored to maintain the seeded plants.

Chestruss Control Prior to Seeding

It is well established that chestruss must be effectively controlled prior to attempts to revegetate chestruss infested rangelands (Hubb and Stewart 1948; Evans and Young 1977; Jordan 1983).

A variety of techniques including mechanical (disking or plowing), burning, grazing and herbicide treatments have been employed to reduce chestruss competition prior to seeding. These treatments vary in their effectiveness according to chestruss phenology, pre- and post-

treatment climatic conditions, soil moisture and timing of treatment. Cost of treatments also varies considerably, ranging from less than \$5 (prescribed burning) to more than \$20 (herbicides) per acre.

Mechanical treatments must bury cheatgrass seed at least 6 cm to obtain effective control (Hulbert 1955). A moldboard plow provides the most effective cheatgrass control but is expensive and not feasible on many rangeland sites due to rocky conditions (Hull and Stewart 1948). Rangeland plows or disk plows are less effective than the moldboard plows in reducing cheatgrass competition but they can be used in moderately rocky rangelands. Plowing or disking treatments must be done prior to cheatgrass seedripeness ("purple" stage) or after fall germination for adequate control.

Properly timed burning can greatly reduce cheatgrass densities the year following the fire (Pehanec and Hull 1945; Stewart and Hull 1949). Stark and others (1946) reported that cheatgrass was effectively controlled (around 90%) by burning in late spring before the seed matured. However, the seed reserve on the soil surface is not totally controlled by burning allowing recovery of the cheatgrass stand in a few years if reseeding with perennial grasses is not successful. Cheatgrass density was reduced from 990 to 139 plants per m² the season after a June burn near Boise Idaho (Pellant 1990).

The cheatgrass plants in the burned plots produced over twice as many seedstalks as did the cheatgrass plants in the unburned plots indicating a rapid recovery of the cheatgrass seed reserve. Burning, regardless of the timing, will reduce but not eliminate cheatgrass from the environment.

Herbicides are another option for controlling cheatgrass competition. Weed control systems utilizing herbicides were developed by Eckert and others (1974) to promote the establishment of perennial wheatgrasses in cheatgrass infested rangelands. Environmental constraints have limited the use of herbicides on public lands to control cheatgrass. In 1991, the Final Environmental Impact Statement for Vegetation Treatment on BLM Lands in Thirteen Western States (USDI 1991) was approved allowing the use of 21 herbicides to control cheatgrass and other weeds. One herbicide in particular, Sulfometuron Methyl, has proved effective in controlling cheatgrass without damage to most perennial native plants in southern

Chemical treatments must have a residual effect at least 6 cm to obtain effective control (Hobbs 1952). A moldboard plow provides the most effective chert control but is expensive and not feasible on many ranges due to rocky conditions (Hall and Stewart 1948). Mechanical plows or disk plows are less effective than the moldboard plow in reducing chert nodules but they can be used in moderately rocky rangelands. Burning or disking treatments must be done prior to chert nodules ("purple" stage) or after fall germination for effective control.

Properly timed burning can greatly reduce chert nodules the year following the fire (Fisher and Hall 1940; Stewart and Hall 1948). Stark and others (1946) reported that chert was effectively controlled (about 70%) by burning or late spring before the seed matured. However, the seed reserve on the soil surface is not really controlled by burning allowing recovery of the chert stand in a few years if reseeding with perennial grasses is not successful. Chert density was reduced from 990 to 138 plants per acre the second year after a fire from near Boise Idaho (Vilant 1960).

The chert plant in the burned pine produced over twice as many nodules as did the chert plant in the unburned pine indicating a rapid recovery of the chert seed reserve. Burning, regardless of the timing, will reduce but not eliminate chert from the environment.

Herbicides are another option for controlling chert nodules. Weed control systems utilizing herbicides were developed by Ecken and others (1974) to promote the establishment of perennial wheatgrass in chert infested rangelands. Governmental agencies have limited the use of herbicides on public lands to control chert. In 1961, the Fish and Wildlife Service issued a report (Stewart and others) on BLM lands in Therman, Oregon (USFWS 1961) which approved allowing the use of 2,4-D herbicides to control chert and other weeds. One herbicide in particular, Salicylic Acid Methyl, has proved effective in controlling chert without damage to most perennial native plants in southern

Idaho. Herbicides, although costly to approve and apply, are the best alternative to control cheatgrass prior to applying restoration practices. Other herbicides effective in controlling cheatgrass are reviewed by Ogg (1994).

Replacing Cheatgrass with Perennial Plants

Once cheatgrass competition has been reduced, the process of replanting perennial vegetation can be started. The replacement of cheatgrass with perennial plants has been a management and research priority in the Great Basin beginning in the 1930's (Piemeisel 1932) and continuing into the 1940's (Hull and Pehanec 1947). A great deal of research was carried out in southern Idaho by A.C. Hull on suitable plant materials to reseed cheatgrass infested rangelands (Hull and Stewart 1948; Hull and Holmgren 1964, Hull 1974). This research clearly indicated that the introduced wheatgrasses i.e. crested wheatgrass were superior to the native grasses in establishing and persisting in cheatgrass infested rangelands.

These findings were collaborated in Nevada by Robertson and others (1966) who found that native species were not as competitive as most introduced perennial plants and the natives did not tend to persist after 5 years.

The use of non native plants to restore rangelands infested with cheatgrass is still a point of controversy. More native plants are being included in the seed mixtures applied after wildfires on public lands administered by the Bureau of Land Management in Idaho (Pellant and Monsen 1993). Cost and availability along with competitiveness in weed infested environments are factors to be considered before deciding to use native or introduced plants to rehabilitate disturbed rangelands.

Greenstripping

A proactive approach to reducing the magnitude of the "cheatgrass-wildfire cycle" is to seed strips of fire resistant vegetation e.g. a greenstrip at strategic locations to slow or stop the spread of wildfires (Pellant 1990). Pellant (1994) describes various criteria to consider when planning a greenstrip project for wildfire reduction. Site preparation and correct selection of plant materials are essential for the establishment of a functional greenstrip. Grazing management after the greenstrip establishment period should be designed to maintain the seeded plants and encourage adequate vegetation utilization to maintain minimal. Greenstripping is not the solution

Herbicide although costly to approve and apply, are the best alternative to control cheaters prior to applying restoration practices. Other herbicides effective in controlling

cheaters are reviewed by Ogg (1994)

Replacing Cheaters with Perennial Plants

Over cheater competition has been reduced, the process of replacing perennial

vegetation can be started. The replacement of cheaters with perennial plants has been a

management and research priority in the Great Basin beginning in the 1930's (Patterson 1972) and

continuing into the 1940's (Hull and Pezarsky 1947). A great deal of research was carried out in

southern Idaho by A.C. Hull as suitable plant materials to reseed cheaters infested rangelands

(Hull and Stearns 1948; Hull and Johnson 1964; Hull 1964). This research clearly indicated

that the introduced wheatgrass, i.e. crested wheatgrass, was superior to the native grasses in

establishing and persisting in cheaters infested rangelands.

These findings were corroborated in Nevada by Robertson and others (1980) who found

that native species were not as competitive as most introduced perennial plants and the natives did

not seem to persist after 2 years.

The use of non-native plants to reseed rangelands infested with cheaters is still a point

of controversy. Most native plants are being included in the seed mixtures applied after wildfires

on public lands administered by the Bureau of Land Management in Idaho (Fellner and Moseley

1992). Cost and availability along with competitive stress in weed infested environments are factors

to be considered before deciding to use native or introduced plants to reestablish disturbed

rangelands.

Conclusions

A primary goal is to reduce the magnitude of the "cheaters-wildfire cycle" as to

seed input to the restored vegetation e.g. a grass strip or strategic location to slow or stop the

spread of wildfires (Fellner 1990). Fellner (1994) describes various criteria to consider when

planting a grass strip project for wildfire reduction. Site preparation and correct selection of plant

materials are essential for the establishment of a functional grass strip. Ongoing management after

the grass strip establishment period should be directed to maintain the seeded plants and

encourage adaptive vegetation succession to maintain balance. Cheating is not the solution

to the "cheatgrass-wildfire" cycle rather it is another tool to help reduce the size and frequency of wildfires.

Summary

Not only is cheatgrass a permanent component of many Intermountain ecosystems, it is the focal point for the disruption of many ecosystem processes and functions. Wildfire cycles are shorter and the severity and extent of the area of fire impacts are greater with cheatgrass in the ecosystem. Wildlife species are affected both directly by alteration of habitat due to cheatgrass invasion and indirectly by the loss of habitat due to increased wildfires. Also, the diversity and cover of microbiotic crusts are diminished with cheatgrass in the ecosystem allowing additional entry of cheatgrass and other weeds. The rangeland health of cheatgrass infested communities is either at risk or already in the unhealthy category with even more undesirable weeds invading some cheatgrass communities.

The solutions to this ecological dilemma are few. Proper management of native rangelands to insure that cheatgrass does not increase is the highest priority. Tools to maintain native rangelands not infested with cheatgrass include the application of good livestock management practices and greenstripping. After disturbance, such as wildfire or drought, rangelands should be reseeded to perennial vegetation if native vegetation recovery is inadequate to preclude invasion of cheatgrass. Use of native species to rehabilitate cheatgrass infested rangelands should be carefully evaluated given site potential, probability of success, cost and availability of native seedstock. Finally, where cheatgrass monocultures are present and resource values are high, rehabilitation or restoration practices may be implemented (at a high cost) to obtain functioning and diverse plant communities.

The influence and impact of cheatgrass in the Great Basin and Columbia River Basin is enormous. The growing concern and interest in the management of cheatgrass infested rangelands is well illustrated by comparing the attendance and emphasis of presentations at two "cheatgrass" symposiums held in the last 20 years.

The first cheatgrass symposium was held in Vale, Oregon in 1965 (USDI 1965). It was attended by 89 participants who listened to 20 presentations with a general theme of learning to

to the "ecosystem-wildfire" cycle rather than to help reduce the size and frequency of wildfires.

Summary

Wildfire is a natural component of many temperate ecosystems. It is the focal point for the development of many ecosystem processes and functions. Wildfire cycles are shorter and the severity and extent of the area of the impact are greater with changes in the ecosystem. Wildfire species are affected both directly by alteration of habitat due to changes in vegetation and indirectly by the loss of habitat due to increased wildfire. Also, the diversity and cover of mammalian plants are diminished with changes in the ecosystem allowing additional entry of herbivores and other species. The ecological health of ecosystems is affected either at the community level or at the individual species level with even moderate wildfire regimes.

The authors in this ecological dilemma are for proper management of native ecosystems. To maintain the ecosystem does not increase in the highest priority. To maintain native plants and animals and related with changes include the application of good livestock management practices and grazing. After disturbance such as wildfire or drought, ecosystems should be restored to pre-disturbance conditions if active vegetation recovery is inadequate to provide services of the system. Use of native species to rehabilitate ecosystems is preferred. Landowners should be carefully evaluated given the potential products of success, cost and availability of native species. Finally, when changes in ecosystems are present and recovery is slow, rehabilitation or restoration factors may be implemented (at a high cost) to obtain functionality and diverse plant communities.

The authors and others of changes in the Great Basin and Columbia River Basin ecosystems. The goal of research and interest in the management of changes is to understand as well as to compare the attributes and emphasis of presentations in two "ecosystem-wildfire" symposiums held in the last 20 years. The first ecosystem symposium was held in Vale, Oregon in 1983 (USDI 1983). It was attended by 89 participants who listened to 20 presentations with a general theme of learning to

live with and making the best of cheatgrass in our ecosystem.

In 1992 a symposium on , "Ecology, Management and Restoration of Intermountain Annual Rangelands" held in Boise, Idaho was attended by 340 participants who listened to 140 presentations. Topics of major emphasis included fire control, rehabilitation strategies, competitive plant materials, greenstripping and habitat restoration. In the 30 years between the two symposiums, the perception of cheatgrass has changed from it being an unwanted but useful component of our rangelands to a threat to the health of the rangeland ecosystems in most of the Great Basin. The increase in cheatgrass related wildfires and the associated loss of rangeland diversity, productivity and private structures, combined with spiraling fire suppression and rehabilitation costs, have all contributed to this change in philosophy about the value and impacts of cheatgrass.

The entry and dominance of cheatgrass on many Great Basin rangelands represents a major challenge to land managers and users (Young and others 1972). No one should be lured into the trap of viewing cheatgrass with a "hopeless attitude" or as a "necessary evil" as Aldo Leopold cautioned almost 50 years ago (Leopold 1949). We must accept the reality that cheatgrass is now a permanent component of many Great Basin rangelands (Young and Evans 1978). We must also explore new management and rehabilitation/restoration approaches for cheatgrass infested areas to stem the tide of additional losses of fiscal and natural resources.

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live with and making the best of changes is our constant.

In 1992 a questionnaire "Technology, Management and Restoration of Intermountain
 Mountaineering" was mailed to 340 participants who returned to 140
 participants. Topics of major emphasis included the control, rehabilitation strategies,
 cooperative plant resources, group dynamics and habitat restoration. In the 30 years between the
 two questionnaires the perception of changes has changed from a being an unwanted but useful
 component of our landscape to a threat to the health of the rangeland ecosystem in most of the
 Great Basin. The increase in changes related wildlife and the associated loss of rangeland
 diversity, productivity and private structure, combined with spiraling fire suppression and
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 changes related areas to meet the risk of additional losses of fiscal and natural resources.

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