Cheatgrass: The Invader That Won the West

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IDAHO STATE OFFICE

1996

INTERIOR COLUMBIA BASIN
ECOSYSTEM MANAGEMENT PROJECT

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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".*

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 m^2 while even higher seed densities ($17,717/m^2$) 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 m^2 in Nevada (Young and others 1969) to 6,500 plants per m^2 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.

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 solstilialis*) 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^{0}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

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/m^2) and a cheatgrass community (465 g/m^2). 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

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

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

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/m^2 greatly reduced growth and survival of crested wheatgrass seedlings. Even cheatgrass densities of 43-172 plants/m^2 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/m^2 . Evans and Young (1977) considered 3 crested wheatgrass plants per m^2 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.

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-

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 seedripe ("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 m^2 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

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 Holmgrem 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 competiveness 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

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

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.

BIBLIOGRAPHY

Aguirre, L.; Johnson, D.A. 1991. Influence of temperature and cheatgrass competition on seedling development of two bunchgrasses. Journal of Range Manage. 44:347-354.

Billings, W.D. 1948. Preliminary notes on fire succession in the sagebrush zone of western Nevada. Bulletin of the Ecological Society of America. 29:30.

Billings, W.D. 1994. Ecological impacts of cheatgrass and resultant fire on ecosystems in the western Great Basin. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 22-30.

Cline, J.F.; Uresk, D.W.; Rickard, W.H. 1977. Comparison of soil water used by a sagebrush-bunchgrass community and a cheatgrass community. Journal of Range Manage. 30:199-201.

Daubenmire, R.F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs. 22: 301-330.

DeFlon, J.G. 1986. The case for cheatgrass. Rangelands 8:14-17.

Dobler, F.C. 1994. Washington State shrub-steppe ecosystem studies with emphasis on the relationship between nongame birds and shrub and grass cover densities. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 149-161.

Eckert, R.E. Jr.; Asher, J.E.; Christensen, M.D.; Evans, R.A. 1974. Evaluation of the atrazine-fallow technique for weed control and seeding establishment. Journal of Range Manage. 27: 288-292.

Evans, R. A. 1961. Effects of different densities of downy brome (Bromus tectorum) on growth and survival of crested wheatgrass (Agropyron desertorum) in the greenhouse. Weeds 9: 216-223.

Evans, R. A.; Young, J. A. 1977. Weed control-revegetation systems for big sagebrush-downy brome rangelands. J. Range Manage. 30:331-336.

Evans, R. A.; Young, J. A. 1978. Effectiveness of rehabilitation practices following wildfire in a degraded big sagebrush-downy brome community. J. Range Manage. 31:184-188.

Friedel, M.H. 1991. Range condition assessment and the concept of threshold- a viewpoint. Journal Range Manage. 44:64-67.

Harris, G.A. 1967. Some competitive relationships between *Agropyron spicatum* and *Bromus tectorum*. Ecological Monographs. 37:89-111.

Hulbert, L. C. 1955. Ecological studies of *Bromus tectorum* and other annual bromegrasses. Ecological Monographs. 25:181-213.

Hull, A.C., Jr. 1965. Cheatgrass--a persistent homesteader. In: Proceedings, cheatgrass

symposium, 1965, July 27-30; Vale, OR. [Portland, OR]: U.S. Department of the Interior, Oregon Bureau of Land Management. 20-26.

Hull, A.C.. 1974. Species for seeding arid rangeland in southern Idaho. Journal of Range Manage. 27:216-218.

Hull, A.C., Jr., and Pehanec, J.F. 1947. Cheatgrass-a challenge to range research. Journal of Forestry. 45:555-564.

Hull, A. C., Jr.; Stewart, G. 1948. Replacing cheatgrass by reseeding with perennial grass on southern Idaho ranges. American Society of Agronomy Journal. 40: 694-703.

Hull, A. C., Jr.; Holmgren, R. C. 1964. Seeding southern Idaho rangelands. Res. Pap. INT-10. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 31 p.

Jordan, G. L. 1983. Planting limitations for arid, semiarid and salt-desert shrublands. In: Managing Intermountain rangelands--improvement of range and wildlife habitats: Proceedings; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11-18.

Kindschy, R.R. 1994. Pristine vegetation of the Jordan Crater kipukas: 1978-91. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 85-88.

Klemmedson, J.O.; Smith, J.G. 1964. Cheatgrass (*Bromus tectorum*). Botanical Review. 30:226-262.

Kochert, M. N.; Pellant, M. 1986. Multiple use in the Snake River Birds of Prey Area. Rangelands. 8: 217-220.

Larsen, L.L.; Sheley, R.L. 1994. Ecological relationships between yellow starthistle and cheatgrass. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service,

Intermountain Research Station. 92-94.

Laycock, W.A. 1991. Stable states and threshold of range condition on North American rangelands-a viewpoint. Journal Range Manage. 44:427-433.

Leopold, A. 1949. A sand county almanac. Oxford University Press. New York, N.Y. 269 p.

Link, S.O.; Gee, G.W.; Downs, J.L. 1990. The effect of water stress on phenological and ecophysiological characteristics of cheatgrass and Sandberg's bluegrass. Journal of Range Manage. 43:506-513.

Mack, R.N. 1981. Invasion of *Bromus tectorum* L. into Western North America: an ecological chronicle. Agro-Ecosystems. 7:145-165.

Mack, R.N.; Pyke, D.A. 1983. The demography of *Bromus tectorum:* variation in time and space. Journal of Ecology. 71:69-93.

Martens, E.; Palmquist, D.; Young, J.A. 1994. Temperature profiles for germination of cheatgrass versus native perennial bunchgrasses. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 238-243.

McLendon, T.; Redente, T. 1992. Effects of nitrogen limitation on species replacement dynamics during early secondary succession on a semiarid sagebrush site. Oecologia. 91:312-317.

Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 416 p.

Murray, R.B.; Mayland, H.F.; Van Soest, P.J. 1978. Growth and nutritional value to cattle of grasses on cheatgrass range in southern Idaho. Research Paper INT-199. Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 57 p.

National Research Council. 1994. Rangeland health--new methods to classify, inventory and monitor rangelands. National Research Council National Academy Press. Washington D.C. 180 p.

Nevada Association of Counties Natural Resource Report- Wildfire Management. 1988. Prepared by Resource Concepts, Inc., Carson City, NV.

Northam, F.E.; Callihan, R.H. 1994. New weedy grasses associated with downy brome. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 211-212.

Novak, S.J. 1994. Quantitative variation within and among cheatgrass populations: the roles of multiple introductions. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 103-108.

Ogg, A.J. Jr. 1994. A review of the chemical control of cheatgrass. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 194-196.

Pechanec, J. F.; Hull, A. C. 1945. Spring Forage lost through cheatgrass fires. Nat. Wool Grower.

Pellant, M. 1990. Unpublished data on file at: U. S. Department of Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

Pellant, Mike. 1990. The cheatgrass-wildfire cycle--are there any solutions? In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 11-17.

Pellant, Mike. 1994. History and applications of the Intermountain greenstripping program. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain

Research Station. 63-68.

Pellant, Mike; Hall, Christine. 1994. Distribution of two exotic grasses on public lands in the Great Basin: Status in 1992. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 109-112.

Pellant, M.; Monsen, S.B. 1993. Rehabilitation on public rangelands in Idaho, USA: a change in emphasis from grass monocultures. Proceedings of the XVII International Grassland Congress. 778-779.

Pellant, M.; Kaltenecker, J. 1996. Unpublished data on file at: U. S. Department of Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

Peters, E.F.; Bunting, S.C. 1994. Fire conditions and pre- and postoccurrence of annual grasses on the Snake River Plain. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 31-36.

Piemeisel, R.L. 1932. Weedy abandoned lands and the weed hosts of the beet leafhopper. Circular 229. Washington D.C.: U.S. Department of Agriculture. 24 p.

Platt, K.; Jackman, E.R. 1946. The cheatgrass problem in Oregon. Extension Bull. 668. Corvallis, OR: Oregon State College. 48 p.

Rickard, W.H.; Rogers, L.E.; Vaughn, B.E.; Liebetrau, S.F. eds. 1988. Shrub-steppe balance and change in a semi-arid terrestrial ecosystems. Developments in agricultural and managed-forest ecology 20. New York: Elsevier. 272 p.

Roberts, T.C., Jr. 1994. Resource impacts of cheatgrass and wildfires on public lands and livestock grazing. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 167-169.

Robertson, J.H.; Eckert, R.E.; Bleak, A.T. 1966. Response of grasses seeded in an *Artemisia*

tridentata habitat in Nevada. Ecology 47:187-194.

Rosentreter, R. 1994. Displacement of rare plants by exotic grasses. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 170-175.

Stark, R.H.; Toers, J..L.; Hafenrichter, A.L. 1946. Grasses and cultural methods of reseeding abandoned farmlands in southern Idaho. Idaho Agricultural Experiment Station Bulletin 267. 36 p.

Stewart, G.; Hull, A. C. 1949. Cheatgrass (Bromus tectorum L.) - an ecologic intruder in southern Idaho. Ecology. 30:58-74.

Sparks, S.R.; West, N.E.; Allen, E.B. 1990. Changes in vegetation and land use at two townships in Skull Valley, western Utah. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 26-36.

Spence, L.E. 1937. Root studies of important range plants of the Boise River watershed. Journal of Forestry. 35:747-754.

Stewart, G.; Young, R.A. 1939. The hazard of basing permanent grazing capacity on *Bromus tectorum*. American Society of Agronomy Journal. 31: 1002-1015.

Swanson, S.; Burkhardt, W.; Young, J.A. 1987. Fact Sheet 87-45. Reno, NV: Nevada Agricultural Experiment Station. 3 p.

Tausch, R.J; Svejcar, T. J.; Burkhardt, J.W. 1994. Patterns of annual grass dominance on Anaho Islands: implications for Great Basin Vegetation Management. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 120-125.

Tipton, F.H. 1994. Cheatgrass, livestock, and rangeland. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings--ecology and management of annual rangelands; 1992, May 18-22; Boise ID, Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 414-416.

Updike, D.R.; Loft, E.R.; Hall, F.A. 1990. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 41-46.

U.S. Department of Interior. 1965. Proceedings, Cheatgrass Symposium, 1965, July 27-30; Vale, OR. [Portland, OR]: U.S. Department of the Interior, Oregon Bureau of Land Management. 88 p.

U.S. Department of Interior. 1991 Final Environmental Impact Statement for Vegetation Treatment on BLM Lands in Thirteen Western States. Bureau of Land Management, Casper, WY.

Westoby, M.; Walker, B.; Noy-Meir, I. 1989. Opportunistic management for rangelands not at equilibrium. J. Range Manage. 42:266-274.

Whisenant, Steven G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 4-10.

Wight, J.R.; Pierson, F.B.; Hanson, C.L.; Flerchinger, G.N. 1992. Influence of sagebrush on the soil microclimate. In: Clary, Warren P., McArthur, E. Durant, Bedunah, Don, Wambolt, Carl L., compilers. Proceedings--symposium on ecology and management of riparian shrub communities; 1991, May 29-31, Sun Valley, ID. Gen. Tech. Rep. INT-289. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 181-185.

Wright, H.A.; Neuenschwander, L.F.; Britton, C.M. 1979. The role and use of fire in sagebrush and pinyon juniper plant communities: a state-of-the-art review. Gen. Tech. Rep. INT-58. Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.

Young, J.A.; Evans, R.A.; Kay, B.L. 1969. Population dynamics of downy brome. Weed Science. 17:20-26.

Young, J. A.; Evans, R.A.; Major, J. 1972. Alien plants in the Great Basin. J. Range Manage. 25: 194-201.

Young, J. A.; Evans, R.A. 1975. Germinability of seed reserves in a big sagebrush community. Weed Science. 23:358-364.

Young, J. A.; Evans, R.A. 1978. Population dynamics after wildfires in sagebrush grasslands. J. Range Manage. 31:283-289.

Young, J. A.; Evans, R.A.; Kay, B. L. 1987. Cheatgrass. Rangelands. 9:266-270.

Young, J.A.; Tipton, F. 1990. Invasion of cheatgrass into arid environments of the Lahontan Basin. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Paul T., compilers. Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 37-40.