

**DOCUMENTS DIRECTLY RELEVANT TO
ANALYSIS OF ALTERNATIVES
IN THE 2002 BUREAU OF LAND MANAGEMENT
ENVIRONMENTAL IMPACT STATEMENT:**

*Vegetation Treatments, Watersheds and Wildlife Habitats on Public Lands Administered
by the Bureau of Land Management in the Western United States, Including Alaska*

Compiled by Josh O'Brien

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FIRE MANAGEMENT

U.S. Department of the Interior. U.S. Department of Agriculture. 1995. Federal Wildland Fire Management Policy and Program Review. Final Report. Washington, DC.

According to the Federal Wildland Fire Management Policy (Fire Policy), "Every area with burnable vegetation must have an approved Fire Management Plan (FMP)."

The highest priority action item needed to implement the Fire Policy is for land managers to develop new FMPs that would allow a full range of "appropriate management responses" to wildland fires. These responses could range from simple aerial monitoring of fires burning in remote roadless or wilderness areas, to aggressive fireline construction where fires threaten to encroach upon human communities. FMPs thus enable managers to place firefighters where they would be most safe, effective, and needed. Without these FMPs, fire managers have only one option: total suppression. Consequently, firefighters are often exposed to prolonged, unnecessary risks and hazards that, in many cases, defy human control efforts and are only extinguished by changes in the weather.

The following key points that are made in the Fire Plan (Executive Summary, p. 1):

- Protection of human life is a priority
- Reintroduce wildfire into the ecosystem
- Every burnable acre will have an approved Fire Management Plan
- More emphasis needed on educating internal and external audiences
- Good Data and statistics are needed to support fire management decisions.

FUELS TREATMENT

Causes of Woody Plant Increase in Western Forests

[A group of scientists and conservation advocates] July 24, 1995 letter to Jack Ward Thomas, US Forest Service Chief, from grazing and conservation groups re: "Livestock grazing is a major cause of forest health problems."

This letter summarizes, with extensive documentation, a matter of central importance to the BLM: The scientific literature that demonstrates that livestock grazing is "a significant cause, potentially the most significant cause, of increased tree density in many forests" (p. 1).

"Scientists have found that livestock grazing causes increased tree densities in two ways:

- 1) livestock consume and lower the density of grasses that would otherwise compete with tree seedlings for space, water and nutrients, and
- 2) livestock remove the herbaceous understory which provides fuel for 'cool' surface fires that kill regenerating trees.

In addition, cattle and sheep directly facilitate conifer invasions into western grasslands by:

- 1) exposing mineral soils and/or destroying cryptogamic (biotic) soil crusts and thereby creating mineral seedbeds, and
- 2) introducing arroyo formation, which dries out meadows and promotes pine invasion."

The letter summarizes three paired studies, spanning thirty years, in which two neighboring and ecologically similar grazed and ungrazed forest sites experienced dramatically different densities of forest trees (with the ungrazed sites with the low tree densities and savannah-type conditions): (1) two ponderosa pine forests in central Washington (one grazed by livestock for 40 years; the other never grazed by livestock; neither burned in 125 years); (2) three plateaus in Zion National Park (one grazed heavily until 1960, the other two never grazed, neither experiencing fires); and (3) grazed and ungrazed ponderosa pine and Douglas fir stands in the foothills of the Bitterroot Mountains in Idaho.

Significantly, this paper is an illustration of the critical scientific role played by leaving some lands in a wild or untreated state. Were it not for the ungrazed comparison areas in each of the studies cited in the letter, it would have been impossible to know that grazing itself – and not simply fire suppression or climate change – is a major cause of the increases in tree density often referred to as a decrease in "forest health."

Belsky, Joy, and Dana Blumenthal. 1995. Ecological assessment of livestock grazing in forests of the western interior United States. Unpublished paper prepared for the Interior Columbia Basin Ecosystem Management Project.

91% of all federal land in 11 contiguous western states is grazed by livestock, but the role of livestock grazing on forest health has not been a focus of agency forest management.

This assessment includes an extensive literature review that suggests livestock grazing plays an important role in degradation of western forests. The substantial evidence compiled in this paper should thus be incorporated into the analysis of Draft EIS alternatives unless the BLM has evidence that refutes it.

Structure, composition and dynamics of western arid forests have been drastically altered. In pre-settlement times, widely spaced tree communities resulted from intense competition from vigorous grass understories and extensive thinning by frequent fire. Tree densities in western interior forests began to increase as livestock grazing and reduced fire frequency altered forest dynamics. Livestock have been observed to: reduce competition between understory plants and tree seedlings; reduce concentrations of fine fuels required to carry cool fires through understories; and browse and trample tree seedlings causing physical damage.

In addition, livestock grazing reduces soil litter (which leads, through increased soil temperatures and soil moisture to changes in vegetative composition, which can lead to further loss of soil litter), and causes compaction and reduced soil infiltration rates (with comparisons between livestock exclosures and grazing), resulting in increased runoff and erosion.

Increased tree densities initiate forest changes – such as establishment of shade-tolerant species, with a shift in species dominance. Dense trees are vulnerable to insect pests and to stand-replacing fire. Selective logging (or high grading) of ponderosa pine and larch has led to increased dominance of fire-sensitive, shade-tolerant trees such as Douglas fir.

The review cites work by Rummell (1951) comparing two unburned plateaus – one grazed and the other not. Ungrazed Meeks Table was characterized by open, park-like forest, with luxuriant herbaceous understory and no tree regeneration, while the grazed area had a dense understory of regenerating trees.

Livestock grazing has cascading effects: As stands become shadier from increased tree densities, species composition changes. Dead woody fuel litter accumulates as dense young trees are stressed and die. Livestock-altered understories have reduced native perennial bunchgrasses, and increased cover of weedy species.

The Report recommends that livestock be excluded from National Forests in the West. “In spite of techniques such as prescribed burning, thinning, salvage logging – stable forests will not develop with continued grazing. Livestock are an important cause of diseased, overstocked and highly flammable forests.

Moreover, and very importantly, many of the effects of grazing can be reversed simply by removing the animals responsible for them:

“With only one single change in management -- protection from livestock grazing -- forests have recovered many of their original ecosystem attributes, including improved soil structure and increased infiltration rates, understory species, reduced tree recruitment, and presettlement-level fire frequencies [citations given]” (p. 29).

[NOTE: This paper, and several others in this section speak to just how important it is for BLM to consider ALL important causes of the vegetation

change that they wish to counter. Increasing tree densities in Eastside forests are often treated as a fire suppression issue, in which case fuel reduction and prescribed burning are among the vegetation treatments considered as solutions to the problem. However, where livestock grazing by itself causes dramatic increases in tree density, reducing grazing intensity may be the only treatment capable of maintaining tree densities at lower levels.

From the perspective of plants' ecological interactions, agency decisions to reduce (or to increase) grazing intensity are just as much a treatment as are decisions to suppress or fight fires in some areas and to intentionally light them in others. To successfully restore native ecosystems, the BLM will have to address all of those management decisions in an area that are, in a biologically relevant sense, treatments.]

Belsky, Joy, and Dana Blumenthal. 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the Interior West. *Conservation Biology* 11:315-327.

A shorter, published version of Belsky and Blumenthal (1995).

Ponderosa pine and mixed conifer forests of the interior West have undergone structural changes as a result of suppression of low intensity fires, and selective logging of larger, older fire-tolerant trees. Livestock grazing is also an important factor that has changed forests. It reduces biomass and density of understory grasses, and reduces abundance of fine fuels. Exclosure studies show that livestock alter ecosystem processes by reducing cover of herbaceous plants and litter, disturbing and compacting soils, reducing water infiltration rates, and increasing soil erosion.

This evidence indicates that there are several causes of structural changes in western forests, and that the role of grazing in increasing tree densities should be considered in restoration plans for exactly the same reasons that fire suppression is usually considered.

Table 1 (pp. 322-323) provides an overview of the scientific studies regarding effects of livestock grazing on herbaceous vegetation, litter, and forest soils in western interior forests of the U.S.

Causes of Woody Plant Increase in Western Shrub- and Grasslands

Archer, Steve. 1994. Woody Plant Encroachment into Southwestern Grasslands and Savannas: Rates, Patterns and Proximate Causes. Pp. 13-68. In: Vavra, Martin, William A. Laycock, and Rex D. Pieper, eds. *Ecological Implications of Livestock Herbivory in the West*. Denver, CO: Society for Range Management.

Archer's treatment of causes of woody plant encroachment in the Southwest and elsewhere is so authoritative and comprehensive that it can't reasonably be

ignored by anyone interested in reversing the degradation of native grasslands. Archer surveys the literature relevant to answering why shrubs and trees have replaced so many grassland landscapes in the past 100 years, and conclude that livestock grazing has been, overwhelmingly, the proximate cause of change.

He argues that: “(1) Atmospheric CO₂ enrichment and directional shifts in climate may have occurred, but have not been sufficient, to cause the vegetation changes observed to date; (2) Fire is not necessarily required to maintain grasslands or savannahs; and (3) Although herbivory, lack of fire, atmospheric CO₂ enrichment and climate have interacted to produce recent vegetation change, selective grazing by large numbers and high concentrations of livestock has been the primary force in altering plant life-form interactions to favor unpalatable woody species over graminoids.” (p. 13)

His arguments are based in large part on detailed discussion of the physiology and ecology of woody vs. herbaceous growth forms, and the advantages of each in relation to CO₂ enrichment, climate, fire, and grazing.

He also lists 11 case studies (p. 51-57), from grasslands/savannahs in the southwest and around the world, in which sites that apparently differ mainly in their history of grazing show dramatically different invasion by woody plants. THIS SET OF CASE STUDIES IS ESSENTIAL: It shows more eloquently than any argument could how invaluable is the existence of reference areas (controls) – in this case ungrazed areas - in allowing managers and others to understand the effects of their management decisions. There simply is no substitute that is as useful.

For the BLM’s vegetation management EIS, this article supports (1) the need to address livestock grazing as the ultimate cause of much of the woody plant invasion in the west and (2) the importance of monitoring the effects of management decisions both on treated areas AND in untreated control areas.

Archer, Steve, David S. Schimel, and Elisabeth A. Holland. 1995. Mechanisms of shrubland expansion: land use, climate, or CO₂? *Climatic Change* 29:91-99.

This is a readable and even-handed evaluation of the four most frequent explanations for shrubland expansion in the west. (It’s a shorter version of the piece cited above). It provides a clear summary of why it is unlikely that increased CO₂ and climate change have caused the spread of shrubs in the arid west – and why most evidence suggests that human-induced changes in **both** fire frequency and grazing intensity are instead the most important causes.

This debate is a contentious one, and bears on BLM decisions to destroy native woody vegetation as a form of “restoration”, I have quoted extensively from the article. The reason that a debate over causes is important to a management plan should be clear: the schedule of treatments necessary to permanently restore native vegetation structure will be very different depending on why the vegetation is “out of whack” in the first place.

On the CO₂ enrichment hypothesis:

On pages 92 and 93, Archer lists eight kinds of evidence (from ecophysiological, modeling, historical, paleohistorical, experimental sources, as well as comparisons between nearby sites) which together strongly indicate that recent CO₂ enrichment hasn't caused shrubland expansion "despite [it's] apparent plausibility." He concludes that, "In sum, these numerous and significant exceptions limit the utility of the historic atmospheric CO₂ enrichment hypothesis as a robust explanation for the cause of woody plant encroachment into grasslands. **The correlation between CO₂ and woody plant invasion may therefore be spurious.**" (p. 93)

On the climate change hypothesis:

"After analyzing land use history and changes in woody plant cover on repeat photography in southeastern Arizona, U.S.A., Bahre felt that **"probably more time has been spent on massaging the climate change hypothesis than on any other factor of vegetation change and yet it remains the least convincing."** He goes on to argue that the historic displacement of grasses by woody plants in this region has been the result of grazing and fire exclusion." (p. 94)

[Note: It's interesting, and maybe not coincidental that the climate change hypothesis, which sees woody plant expansion as being caused by factors outside human control, has been so popular. To the extent that climate really has little to do with recent shrubland expansion, that popularity is a useful reminder of a general tendency to want to ignore management's role in causing changes in vegetation.]

On the grazing hypothesis:

Archer's evidence for grazing's role in favoring shrubland expansion comes from several sources. One category of evidence is mechanistic: "Direct and indirect effects of livestock grazing (preferential utilization of grasses, alteration of soil structure and chemistry, woody legume seed dispersal, reductions in fire frequency and/or intensity) significantly influence woody plant population dynamics, generally enhancing woody plant seedling establishment, seed production, plant longevity and stand development. (p. 96)

Another form of evidence is the repeated temporal and spatial correlation of grazing with the spread of woody plants. For instance, Archer points out, "Scenarios parallel to those of the North American Southwest have also occurred in Africa, Australia, and South America following the introduction of livestock. The widespread invasion of woody plants into grasslands and 'thicketization' of savannas is often coincident with intensification of grazing." (p. 96)

A figure on page 95, which plots recruitment in a Utah ponderosa pine forest along with changes in CO₂ and livestock increase and decreases, is an example of the kind of evidence that can distinguish between putative causes of vegetation change. It is for this reason that we suggest that BLM both monitor

the results of its management decisions and leave aside untreated controls for comparison where possible.

In conclusion:

“Encroachment of woody vegetation into grasslands and savannas reported for many arid and semi-arid systems in recent history have likely involved interactions between climate, atmospheric CO₂-enrichment, fire and grazing. . . . However, case studies documenting differences in the rate, pattern and extent of woody plant encroachment suggest that regional factors such as historic changes in climate or atmospheric CO₂-enrichment were not the proximate factors driving local changes in vegetation. . . . In contrast, numerous case studies have established a strong link between direct and indirect effects of livestock grazing and the encroachment of unpalatable woody plants into arid and semi-arid ecosystems. **Differences in livestock species and levels of grazing pressure across landscapes over time would also explain why rates, patterns and dynamics of vegetation change have varied substantially for similar habitats experiencing similar climates and similar levels of post-industrial CO₂ enrichment.” (p. 96-7)**

Belsky, A.J. 1994. Review of the scientific assessment of western juniper woodlands of the Pacific Northwest. Interior Columbia Basin Ecosystem Management Project. Walla Walla, WA.

There are only 932,000 hectares of western juniper woodlands in Oregon and a total of 1,614,000 hectares in WA, OR, ID, CA, and NV, indicating the area covered by western juniper is significantly smaller than that usually reported (approx. 5% of eastern Oregon). Juniper expands its range during wet periods, and retracts during dry, but the current expansion differs.

Juniper and grasses compete for water and nutrients in the same soil horizons as grasses and forbs, explaining how grasses can outcompete junipers. 62-65 of total juniper biomass is above ground, with implications for juniper control and prescribed fire. Junipers tolerate nitrogen-deficient soils. Young junipers prefer mesic sites and non-competitive environments. Grazed fescues lose competitive abilities with cheatgrass. Junipers can grow in nutrient-deficient habitats. Juniper encroachment may increase biodiversity. Pristine communities such as “the Island” show natural range of variability.

“A lack of information about the interactions between junipers and livestock grazing has led to many conflicting and spurious results in studies of herbaceous vegetation in juniper woodlands”. Studies on juniper community dynamics and management have not controlled livestock grazing, and the effects of trees and grazers are completely confounded. Junipers invade when grazing reduces fire frequency. Fire and grazing increases cheatgrass in juniper woodlands. Juniper increases when grazing reduces competition from grasses.

Microbiotic crusts, essential for healthy shrub-steppe systems, are destroyed by livestock trampling. Crusts increase water infiltration, reduce erosion, are the

main nitrogen fixers in western rangelands, benefit native vascular species, increase soil carbon. Crusts may recover if livestock are removed.

Belsky lauds the report for reporting data instead of myths on juniper: Junipers do not reduce water infiltration and do not increase soil erosion.

Problems with “conversion” attempts for juniper woodlands include the following:

1) Chemical control may increase undesirable species, while other types of juniper control spread introduced annual weeds; control may reduce Ponderosa pine.

2) Removal may significantly deplete soil nutrients. Older trees sequester nutrients that are stored in aboveground bole, branches and foliage. Burning or logging these trees could severely affect nutrient-deficient sites. Such nutrient losses may be one reason arid systems are crossing “thresholds” sensu Laycock, into new, less productive stable sites (see also article by Schlesinger et al 1990 summarized below). Whole tree removal could cause significant depletion of carbon, nitrogen and other nutrients.

Grazing management of western juniper woodlands – lower utilization levels (10-25%) proposed in report may be too high, as the authors admit that with grazing, junipers will incrementally gain site dominance and restrict recovery.

Belsky’s major area of disagreement with the report is its focus on climate change and carbon dioxide enrichment as causes of recent juniper expansion, and states these effects are small compared to the effects of livestock grazing in reducing fire frequency and removing competitively dominant grass species, and are beyond the control of land managers.

If the goal of land management is to reduce areal extent of junipers, managers must address the following: A significant portion of the nutrient capital of nutrient-poor western ecosystems is tied up in aboveground juniper biomass. Fire or physical removal will reduce the nitrogen and carbon in these systems. Managers must also address the problem of exotic weedy species - such as cheatgrass and medusahead wild-rye – which are likely

With reduced livestock grazing in Utah, pinyon-juniper woodlands increased in herbaceous and shrub cover and decreased in tree density. “It is possible that native species can be restored to a site after juniper control, but current research suggests massive intervention with heavy equipment, fire and herbicides may be required, and these techniques are expensive, further damage range ecosystems and have been proven to be only marginally effective.

Eddleman, L.L., P.M. Miller, R.F. Miller and P.L. Dysert. 1994. Scientific assessment of western juniper woodlands (of the Pacific northwest). Interior Columbia Basin Ecosystem Management Project.

This is the report critiqued by Belsky above.

Belsky, A. Joy. 1996. Viewpoint: Western juniper expansion: Is it a threat to arid northwestern ecosystems? *Journal of Range Management* 49: 53-59.

This article debunks myths associated with western juniper and pinyon-juniper communities, i.e. that junipers are weedy nuisances invading and degrading arid lands.

Western juniper is a native plant that has expanded in range and abundance in the last 100 years. Belsky reviews evidence of range expansions by juniper in the last 5,300 years to show that the juniper dominance of some ecosystems in the west is not an unnatural or recent phenomenon. She presents evidence that: 1) the species' current expansion is chiefly attributable to grazing by livestock and not to climate change and 2) removal of juniper does not improve ecosystem processes.

(1) Evidence that grazing has caused juniper range expansion:

An important piece of evidence indicating that climate is not “to blame” is that past range expansions of juniper have happened during relatively mesic periods. Current conditions, by contrast, are becoming more xeric. That evidence combines with the close temporal association between juniper expansion and the introduction of large numbers of grazing animals to the region to indicate that grazing by livestock has been the cause of the shift from dominance by grasses to dominance by junipers.

Some of the ecological mechanisms underlying the shift are decreases in root competition by grazed grasses with seedlings of woody plants, and a decrease in fire frequency (due to loss of fine fuels from grazing). **(p. 53)**

Belsky concludes, and the BLM needs to address the proposal, that “Western juniper . . . should not be referred to as an invasive weed that is threatening natural communities, but as a native species that becomes a community dominant under certain environmental conditions” **(p. 55)**

(2) Lack of evidence that removing juniper improves ecosystem characteristics:

Next, Belsky looks at what evidence there is to support the idea that removal of juniper can improve ecosystem characteristics, and finds scant if any support in the experimental literature. Junipers do intercept precipitation and transpire water, but that is not enough to conclude that juniper wooded communities perform more poorly at maintaining stream flows or absorbing water than do other communities. Among other complicating factors, herbaceous plants and shrubs that replace trees also intercept rain and snow, and also transpire and deplete soil moisture; and tree removal exposes the soil and understory plants to more sun (higher temperature and evaporation) and also to more wind (higher evaporation).

Belsky decided, in this case, to look at the best facts available, the results of experiments that compare actual juniper woodlands with and without removal. She found first that there have been few well controlled experiments, and then that those that have been performed show little support for the idea that junipers degrade ecosystem function.

“In spite of the conviction that junipers are degrading western rangelands and wildlife habitat, there is little or no experimental evidence suggesting that this is so or that juniper control will (1) increase water yield to springs and streams, (2) increase water infiltration, (3) reduce erosion, or (4) improve fish and wildlife habitat.” (p. 57)

“If annual weeds are abundant before treatment, juniper control may open the site to increased dominance by annual grasses and forbs”.

Finally, she closes with a quote from Gifford (1987), discussing what he called the myths and fables that have grown up around the pinyon-juniper community type:

“It seems reasonable to suggest that before large sums of money are expended to modify a plant community, that baseline data be gathered to reflect existing conditions. . . and then, if change is initiated, that data be collected to substantiate whether or not any of the initial objectives were met. If baseline and post-treatment evaluation monies are not available, then the project should never be approved. This equates to professional accountability”

Schlesinger, William H., JF Reynolds, GL Cunningham, LF Hueneke, WM Jarrell, RA Virginia, and WG Whitford. 1990. Biological feedbacks in global desertification. *Science* 247: 1043-1048.

Provides a sobering reminder that arid ecosystems are fragile, and can be irreversibly degraded. Desertification is not just a phenomenon that takes place overseas or across the border. This report puts the conversion of semi-arid grasslands to shrub dominated deserts into a global perspective.

“Any directional shift to a greater area of arid land potentially represents a permanent loss in the productive capacity of the biosphere on which all life depends.” (p. 1043)

The authors' hypothesis is that desertification results when a grassland ecosystem, with relatively uniform distribution of soil resources (chiefly water and N), is replaced by a shrub dominated community, which thrives on a more patchy distribution of resources. Since shrubs further localize soil resources, a cycle of increasing degradation results, making the shift in community type semi-permanent.

The authors emphasize the role of humans (and their commensals) in causing desertification:

“Large herds of domestic livestock disrupt this tight connection of soil and plant processes and lead to a decline in the cover of black grama and other species in semiarid grasslands. Heavy grazing during the short summer wet season contributes to the loss of grass cover during moderate drought and to lowered competitive potential of grasses. Trampling compacts the soil and reduces infiltration rates. Greater runoff results in erosion and increased transport of water, N, and other plant nutrients between geomorphic units in the basin.” (p. 1044)

“Grazing increases soil heterogeneity in semiarid lands, and the conversion of these areas to shrub-desert is aided when cattle disperse the seeds of desert species such as mesquite. Similarly, greater soil heterogeneity caused by off-road vehicles leads to the degradation of desert areas by increasing the channelization of runoff and the rate of soil erosion.” (p. 1047)

[Note: The degradation that the authors describe from the Jornada Experimental Range is self-sustaining: it may now be impossible to return the area to its native vegetation. In such areas, the most important vegetation treatments managers have at their command may be those (such as stocking rates) that affect the likelihood of initial degradation.]

Schmidt, L.J. 1987. Present and future themes in pinyon-juniper hydrology. Pp. 474-489. In: Everett, R.L., (ed.). *Proceedings. Pinyon-Juniper Conference*. USDA Forest Service General Technical Report. INT-215.

Points out flaws in understanding of pinyon-juniper hydrology, and land managers lack of knowledge of inventory methods, silvicultural systems, and productivity in relation to runoff processes.

“Acquiring understanding of the pinyon-juniper ecosystem challenges our current research technology. The highly variable site condition, limited number of events that produce runoff, and time references all combine to create a complex study environment. “

Negative impacts of fuel reduction treatments (thinning, chaining, burning)

Fox, Joseph W., and Timothy Ingalsbee. 1998. Fuel Reduction for Firefighter Safety. *Proceedings of the International Wildland Fire Safety Summit*, Winthrop, WA, Oct. 26-29, 1998. Fairfield, WA: International Association of Wildland Fire.

This paper questions the need for canopy fuel reduction to reduce wildfire hazard and/or to introduce prescribed fire. It counters the argument that commercial thinning to reduce canopy densities increases firefighter safety, prescribed fire efficiency during wildfire suppression or for future prescribed burning.

“Changes in vegetation and stand structure: The hazardous fuels reduction program can impact wildland firefighter safety by changing the vertical structure

of fuel and plant species composition, age, and size. If mechanical thinning becomes a major component of the program, then not cleaning up the debris represents the greatest threat to firefighters. In controlled tests that simulated wildfire occurrence, Weatherspoon and Skinner (1995) found that uncut stands suffer the least fire damage, followed by partial-cut stands with fuel treatment; but partial-cut stands with no fuel treatment had the most damage (p. 6).”

The paper cites evidence that logging can increase fire spread and fireline intensity, increasing the likelihood of severe fire effects.

“In FARSITE fire behavior computer simulations, stands with canopy cover of 40% or less function the same as open stands (Finney et al., 1997). Thinning causes more solar radiation to reach the forest floor and results in lower fuel moisture, higher windspeeds, and faster brush and grass growth and maturation (p. 6)”

Crown fires can be reduced with manual pre-treatments (non-commercial thinning, pruning and hand piling) as well as increase firefighter safety and improve ecosystem health.

Oregon Department of Fish and Wildlife. 1994. *Juniper woodland management.* ODFW Habitat Conservation Division. Portland, OR.

The report cautions: “Proposals to convert juniper to shrub or grassland types that do not address the underlying causes for the increase of juniper may actually have adverse effects on wildlife and other resource values, and will not result in the desired permanent resource recovery. Large-scale projects designed to capture marketable juniper values may also have adverse consequences for wildlife habitat.”

“Potential commercialization of the juniper resource also poses concerns for wildlife managers” – using the example of a proposed chipping facility. Several authors caution that factors and processes driving vegetation change in juniper systems are complex, largely site specific, and without a thorough site- history analysis, the consequences of intervention (or non-intervention) cannot be anticipated”.

Wildlife: Uses include diverse reproductive, feeding and protective cover functions – values are greatest at ecotone between juniper and sagebrush types. Large, mature old growth individuals provide the most diverse wildlife use opportunities and are an extremely valuable habitat component. There is seasonal and year-to-year variation in wildlife species presence.

Provides wildlife species list by geographic province. “Because most wildlife species respond to the structure of vegetation more than to plant species composition, management that alters or reduces the structural diversity of juniper stands has important consequences for wildlife diversity. Provides numbers of species adversely affected by changes in juniper habitat., and provides management recommendations.

Montana Department of Fish, Wildlife and Parks. 1995. Ecological implications of sagebrush manipulation.

Discusses importance of sagebrush to wildlife, as food and cover, historical occurrence of big sagebrush, and impacts of manipulation of sagebrush.

There is no evidence that sagebrush treatment results in greater yearlong habitat carrying capacity for sage grouse and antelope. Controlled burns are not always beneficial for wildlife. FWP does not support the assertion that fire is necessary to create habitat diversity claimed to be lacking in mature sagebrush stands.

Well-managed sagebrush grasslands inherently contain vegetative diversity. "The logic that we must make up for the lack of wildfires by using controlled burns to maintain vegetative landscapes in optimum and diverse conditions overlooks the fact that diversity often already exists. No evidence supports the "need" to manipulate a sagebrush stand to maintain it in a healthy condition over time. Sagebrush communities have been shown to survive and maintain their productivity for long periods."

Washington State University Cooperative Extension. 2001. Managing western juniper for wildlife. Woodland Fish and Wildlife. U.S. Department of Agriculture, September 2001

This paper emphasizes that when managing juniper for wildlife it important to maintain a balance of plant layers, including wild flowers, grasses, shrubs and trees. Juniper is important thermal cover for wildlife during severe winter conditions.

The paper points out that two common tools are used for reducing juniper – fire and cutting. The use of chemicals has produced mixed results and they are not often used.

The selection of the tool to manage juniper for wildlife depends on **(p.5)**:

- 1) site potential
- 2) condition of site
- 3) stage of woodland development
- 4) size of area
- 5) objectives

In managing juniper for wildlife, it is important to consider both the community and landscape levels.

Old growth juniper is important to protect for wildlife **(p. 5)**.

The paper makes recommendations for managing both good and poor sites. In poor sites, do not burn juniper communities that have limited understory plants and understory of cheat grass or other exotics. Juniper communities in poor

conditions can not burn due to insufficient fuel and burning can cause further degradation (p. 7).

Burning juniper can:

- 1) increase weed spread
- 2) expose bare ground which accelerates erosion
- 3) in extreme conditions, crown fires can sweep across poor sites especially if cheatgrass or medusahead are abundant in the understory (p. 7).

If trees are cut, leave limbs on ground to benefit wildlife instead of spreading chips. Spreading limbs on the ground creates groundcover that protects the soils from erosion, provides sites for seedlings to establish in the understory, and provides cover for wildlife (p. 7).

Wildlands-Urban Interface

Cohen, Jack D. 1999. Reducing the wildland fire threat to homes: where and how much? USDA Forest Service Gen. Tech. Rep. PSW-GTR-173. www.firelab.org

Dr. Jack Cohen, a Research Physical Scientist, studies the effects of fires on the ignitability of houses and the methods of protecting them from forest fires. Dr. Cohen and other researchers at the Missoula Fire Sciences Laboratory at the Rocky Mountain Research Station in Missoula Montana are responsible for the majority of the most recent research regarding physical effects of forest fires on houses and structures. Publications by the Fire Lab staff can be found at www.firelab.org.

Dr. Cohen's research, based on extensive modeling, concludes that the W-UI home loss problem is an ignitability issue and is largely independent of wildland fuel management issues. "SIAM modeling, crown fire experiments, and W-UI fire case studies show that effective fuel modification for reducing potential W-UI fire losses need only to occur within a few tens of meters from a home, not hundreds of meters or more from a home (p. 192)."

He argues against wildland fuel reduction to protect homes in the wildland urban interface. Cohen stated, "The evidence suggests that wildland fuel reduction may be inefficient and ineffective: inefficient because wildland fuel reduction for several 100 meters or more around homes is greater than necessary for reducing ignitions from flames; ineffective because it does not sufficiently reduce firebrand ignitions (p. 192)."

Cohen also argues that "Wildland vegetation management does not effectively change home ignitability (p. 193)." It is not that there may not be a purpose for wildland vegetation management, but it is "imperative to separate the problem of the wildland fire threat to homes from the problem of ecosystem sustainability due to changes in wildland fuels (p. 193)."

The paper concludes that the homeowner is responsible for home ignitability, rather than the fire services being responsible for all pre-suppression and fire protection activities. The role of the fire services is to be a community partner to provide home owners with technical assistance and fire response.

Cohen, Jack D. Wildland-urban fire — a different approach. Missoula Fire Sciences Laboratory. Rocky Mountain Research Station. USDA Forest Service. www.firelab.org

This paper argues that there is a need for a different approach to reducing the wildland-urban interface problem.

The focus needs to be on community compatibility with wildland fire rather than the prevention of fire encroaching on a community.

“Residential fire destruction is the principal problem during wildland-urban fires, but homes that do not ignite do not burn. Recognizing the potential for wildland-urban home ignitions and preventing home ignitions is the principal challenge (p. 1).”

Cohen defined the home ignition zone based on research that indicates that the “potential for home ignition depends on the home’s fuel characteristics and heat sources within 100-200 feet adjacent to a home (p. 1).”

“Given a wildland-urban fire, the home ignition zone principally determines the potential for home ignitions. This suggests a management approach that focuses on preventing home ignitions. That is, we reduce a community’s vulnerability to wildland fire rather than attempting the elimination of wildland fire encroachment (p. 3).”

The paper concludes that agencies need to recognize that wildland-urban fire problems must be dealt with using different strategies and tactics than traditionally. They need to focus on the home ignition zone before wildfires occur. Agencies must work with land owners as partners and facilitators for implementing mitigations in the wildland-urban interface.

EXOTIC SPECIES

Proactive Strategies for Preventing Exotic Invasions

Elton, Charles S. 1958. *The Ecology of Invasions by Animals and Plants*. Methuen and Co. Ltd. London.

This is the first book ever written about invasive organisms, by a famous British ecologist. In Chapter Six, Elton anticipates the importance of maintaining ecosystems’ resistance to invasion, rather than simply focusing on “new

technological means of suppressing this plant or that animal” as the best way to keep populations of already established exotics within bounds.

“By the end of this book I intend to carry the argument some way towards showing that we are faced with the life-and-death need not just to find out new technological means of suppressing this plant or that animal, but of rethinking and remodeling and rearranging much of the landscape of the world that has already been so much knocked about and modified by man; while at the same time preserving what we can of real wilderness containing rich natural communities. In other words we require fundamental knowledge about the balance between populations, and the kind of habitat patterns and interspersion that are likely to promote an even balance and damp down the explosive power of outbreaks and new invasions.” (p. 110)

Elton understood, back in 1958, that the invasion of species into communities involves the biology both of the invaders and of the communities they are entering. Thus, he reasoned, prevention of invasions needed to involve both vigilance for newly introduced organisms AND prevention of the conditions that reduce communities' resistance to invasions.

That is a common insight among invasion biologists, including those cited in this section, and is one that the BLM needs to incorporate in its management strategies.

[Note: To the extent that the BLM views fire suppression as a cause of woody plant invasion, and aims to restore natural fire to maintain non-woody vegetation, it is engaging in just this sort of long range thinking based on an understanding of causes. It is important that the same type of thinking (and management response) be applied to other causes of invasion, including livestock impacts, ORV traffic, herbicide use, road construction and use, mining, and so on.]

Hobbs, Richard, and Stella Humphries. 1994. An integrated approach to the ecology and management of plant invasions. *Conservation Biology* 9:761-770.

A fine review of noxious weed management, focusing not only on controlling the invading plant and limiting the introduction of potential weeds, but on managing ecosystems to prevent or control weed invasion, and prioritizing invaded ecosystems for their value and ecosystem vulnerability.

Richard Hobbs is an Australian ecologist and expert on biological invasions. He and Humphries argue that, “**current research and management approaches [which “focus mostly on the the characteristics and control of invading species”] are inadequate to tackle the problem [of plant invasions].**” They suggest that “**a focus on the invaded ecosystem and its management, rather than on the invader, is likely to be more effective.**”

"Where invasion is initiated and enhanced by the predominant management regime (current patterns of stock grazing), one must inevitably question whether that management regime is appropriate" (p. 765)

"This concept of focusing on the invaded ecosystem rather than the invader has yet to be fully embraced by conservation managers. It is becoming increasingly clear that ecosystems vary in their susceptibility to invasion and that this susceptibility can be altered by management activities. Of course not all invasions can be directly linked to particular ecosystem modifications. . . . But ecosystem characteristics and their modification often do have a direct bearing on the success or failure of particular invasions, and some generalizations concerning this are emerging. It is becoming generally accepted that **disturbance** is a major factor affecting the invasibility of natural ecosystems."

"Cale and Hobbs (1991) and Humphries et al. (1991) have argued that attempts to control weeds without addressing the causes of the invasion are doomed because they treat symptoms rather than causes. The changes in ecosystem structure or processes that allow the initiation or intensification of weed invasion have to be addressed before effective weed control can be achieved." (p. 765)

"For example, MacLeod et al. (1993) suggest that control of woody weed invasion in Australian rangelands may require removal of grazing pressure and reinitiation of periodic fires. Brown and McIvor (1993) also advocate periodic fire as a potential way of limiting weed spread but this in turn demands that sufficient fuel be allowed to build up. This generally can happen only in the absence of stock grazing." (p. 765)

"...[S]ome assessment of the reversibility of ecosystem change needs to be made so that the likelihood of success of control programs can be estimated" (p. 766).

Figure 4 (p. 766) helps with prioritization of noxious weed management efforts. Among sites that are of value and are relatively undisturbed, "the management objective should be to keep them that way," as "fortresses" (p. 766).

For "sites of high value that are subjected to greater levels of disturbance and that hence are more susceptible to invasion....[, the] management objective here should be to change these sites to high value and low disturbance by reducing or removing the disturbing influence, controlling current invasions, and preventing further invasion" (pp. 766-767).

"Most of today's weed problems arise from past and present human activities" (p. 767).

"An integrated program of prevention, detection, early control, and ecosystem management carried out at all stages of the invasion process is required" (p. 768, emphasis added). [Note: This could serve as a mission statement for the BLM's invasive and noxious weed management program.]

"Socioeconomic analysis may dictate that some weed problems are untreatable, or conversely that their successful treatment may require radical changes in land use" (p. 768).

Luken, J.O. 1997. Management of plant invasions: *Implicating ecological succession*. In *Assessment and management of plant invasions*, J.O. Luken and J.W. Thieret, eds. 133-144. New York: Springer-Verlag.

This chapter describes an ecological approach to managing invasive species. It contrasts traditional weed science, "directing chemical, physical, or biological control methods at the problem species; success is typically measured in terms of kill" with management "directed at the full range of processes contributing to system change through time with success measured as both positive and negative changes of participating species" and concludes that "the latter approach is preferred."

Mack, R.N. et al. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. *Ecological Applications* 10(3): 689-710.

This technical report describes the importance of prevention and the need to address underlying causes of invasive species problems. "Effective prevention and control of biotic invasions require a long-term, large-scale strategy rather than a tactical approach focused on battling individual invaders. **An underlying philosophy of such a strategy should be to establish why nonindigenous species are flourishing in a region and to address the underlying causes rather than simply destroying the currently most oppressive invaders.** System management, rather than species management, ought to be the focus." (emphasis added)

Masters, Robert A., and Roger L. Shelley. 2001. Invited synthesis paper: Principles and practices for managing rangeland invasive plants. *Journal of Range Management* 54: 502-517.

A mainstream, uncontroversial synthesis and framework for managing rangeland invasive plants, by a Dow Agrosiences biologist, and a professor at Montana State University.

The third and fourth sentences of the article are the following: "The invasion process is regulated by characteristics of the invading plant and the community being invaded. The presence and spread of invasive plants is often symptomatic of underlying management problems that must be corrected before acceptable, long-term rangeland improvement can be achieved."

An important theme throughout this article is that human activities affect invasibility of plant communities, and that the impact of those activities needs to be considered as part of any plan to limit the spread of invasives.

Particular emphasis is given to the role of disturbance in increasing invasibility by exotics:

- "Past rangeland management practices and climatic changes have contributed to plant community shifts by altering disturbance regimes that have accelerated invasive plant establishment and expansion." (p. 503)

- “Disturbance often increases safe site availability for invasive plant establishment (5 references). . . Events that affect resource availability and community demographic processes such as fire, storms, floods, grazing management, and fertilization are considered to be disturbances. Roads are disturbances that provide corridors for invasive plant dispersal and alter the physical and chemical components of the environment, which further facilitate invasion.” (p. 505)
- “Community susceptibility to invasion is increased when disturbances deviate from historical patterns because the resident species are not adapted to the new disturbance regime.” (p. 505)

MacDonald, I.A.W. et al. 1989. Wildlife conservation and the invasion of nature reserves. Pp. 240-255 in: Drake, J.A., H.A. Mooney, F.DiCatri, R.H. Groves, F.J. Kruger, M. Rejmanék, and M. Williamson, Eds. *Biological Invasions: A Global Perspective*. Wiley & Sons, Chichester.

In this chapter of a classic work on biological invasions, the authors caution that control methods for invasive species in natural areas are not effective unless:

1. Reserve managers must “identify and subsequently eliminate or ameliorate changes in disturbance regimes which are beyond the evolutionary experience of the native biota”;
2. Must “identify keystone introduced species which themselves give rise to ecosystem-level impacts”;
3. “Successful elimination or control of invasive introduced species has only been possible where management has been initiated during the early stages of the invasion”;

The “critical importance of follow-up control operations must be recognized and budgeted for from the outset” (p. 246-247).

Naylor R.L. 2000. The economics of alien species invasions. In: H. A. Mooney, and R. J. Hobbs, editors. *Invasive species in a changing world*. Island Press, Washington, D.C.

Limited resources are frequently cited as the reason that agencies are not able to effectively combat invasions. Naylor’s paper provides a strong case that agencies’ common focus on reactive measures such as herbicide treatments and chaining—treating weeds only after they have already invaded beyond the possibility of eradication—is so economically inefficient that it may be THE reason that there are insufficient funds for prevention.

Naylor’s paper provides strong evidence that taking management measures to prevent invasions is not only the best means, ecologically, to successfully

prevent and control exotic species invasions, but also the most economical approach.

Rejmánek, M. 1989. Invasibility of plant communities. Pp. 369-388 *in*: J.A. Drake, H.A. Mooney, F.D. Castri, R.H. Groves, F.J. Kruger, M. Rejmánek, and M. Williamson, eds. *Biological Invasions: A Global Perspective*. Wiley and Sons, Chichester, England.

A plant ecologist and expert on biological invasions, Marcel Rejmánek reviewed the scientific literature to determine what the factors are that confer resistance to invasion and what factors contribute to invisibility of plant communities. It was clear that “there is overwhelming evidence that several types of disturbance promote biological invasions,” and that “the amount of biomass or cover may be the most efficient indices of community resistance to invasions in some situations” (p. 381). His research also suggests that “**biomass destruction might be the only really general factor responsible for plant invasions.**” It is likely, therefore, that a failure to address the sources of biomass destruction is also likely to lead to failure to effectively control invasive species.

Rejmánek also found evidence from several studies showing a positive relationship between increasing maturity or age of the plant community, and a reduction in non-native invasive species (p. 371). Efforts to reduce the impacts of invasive non-native species must concentrate on protecting mature, late seral plant communities from disruptions that are outside the evolutionary disturbance history.

Treating species without treating causes

Groves, R.H. 1989. Ecological control of invasive terrestrial plants. Pp. 437-461 *in*: Drake, J.A., H.A. Mooney, F.D. Castri, R.H. Groves, F.J. Kruger, M. Rejmánek, and M. Williamson, eds., *Biological Invasions: A Global Perspective*. Wiley & Sons, Chichester.

A recognized expert in the field of biological invasions, Richard Groves defines the use of ecological control of invasive plants as “the planned use of one or several methods of control when integrated with an understanding of the dynamics of the ecosystem in which the plant occurs.” Reviewing a number of case studies, Groves found that invasive plant control on agricultural lands results in simplifying the system, while ecological control methods in natural systems, “on the other hand, aim to maintain or even to enhance biological diversity in the longer term” (p. 437). Noting the widespread use of herbicides to control weeds on agricultural lands, and a decided ‘agronomic bias’ applied to management methods in natural areas, Groves notes that control of invasive plants by herbicide application is usually short term and directed at individual ‘target species’ while other, equally invasive species are ignored. Groves determined that “**chemical control of already widespread invasive plants in nature reserves is often expensive, usually ecologically undesirable, and rarely, if ever, effective in the long term, unless integrated with other**

methods of control” (p. 440, emphasis added). In addition, Groves presents four essential principles of control relative to invasive plants in natural areas:

- 1) A combination of methods is needed to achieve effective control of terrestrial invasive plants.
- 2) “Control methods which simplify the ecosystem and reverse the trend towards diversification of the system seem to be more prone to subsequent invasion by other groups of invasive plants, the end result of such actions being to replace one invasion with another.” [This is also known as weed shifting.] For example, a combination of methods that includes changing the fire frequency, deliberate planting of competing plants, use of biological control agents—insects, or fungi, etc.—have the potential to increase diversity and “produce an ecosystem which may be better able to resist further invasion.”
- 3) “Once initiated, control methods have to be maintained.”
- 4) Long term monitoring of the effectiveness of control measures is a necessity.

Masters, Robert A., and Roger L. Shelley. 2001. Invited synthesis paper: Principles and practices for managing rangeland invasive plants. *Journal of Range Management* 54: 502-517.

The same paper cited in the above section.

“Control of invasive plants may only open niches for establishment of other undesirable plants, unless desirable plants are present to fill the vacated niches.” **(p. 502)**

Noble, I.R. and R.O. Slatyer. 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio* 43:5-21.

Noble and Slatyer propose a scheme to predict the successional patterns in plant communities subject to recurrent disturbances. The authors cite Egle (1954) who determined that “the ‘initial floristic composition’ following disturbance determines the future shifts in dominance” **(p. 5)**. Another important aspect is the “inhibition pathway” whereby “later species cannot grow to maturity in the presence of earlier ones. Unless they are present on the site their entry may be inhibited by the earlier occupants, thereby leading to dominance by species not normally regarded as late successional species” **(p. 5)**. This underscores the necessity of ensuring that native seeds and parent plants are available on site wherever invasive non-native plant control measures are planned. If exotic species are killed and natives are not available for recruitment, exotic species are likely to become reestablished.

Randall, John M. 1996. Weed control for the preservation of biological diversity. *Weed Technology*. 10:370-383.

John Randall is a weed specialist for The Nature Conservancy, based at UC Davis.

“There is the risk that when one pest is eliminated another will take its place, i.e., the infestation is merely the symptom of a more fundamental problem. For example, in Douglas County Oregon, St. Johnswort (*Hypericum perforatum* L.) populations were sharply reduced by biocontrol agents only to be replaced by tansy ragwort (*Senecio jacobaea* L.) which was in turn sharply reduced by biocontrol agents only to be replaced by Italian thistle (*Carduus pycnocephalus* L.). Eric Coombs, an entomologist with the Oregon Dep. of Agriculture, believes that while biological control may eventually reduce Italian thistle, there is a good chance the thistle will be replaced by another pest and then another in an endless series, unless cultural practices in the area are changed.”

Evidence for the Role of Diverse and Vigorous Native Communities in Preventing Invasion

Naeem, S. et al. 2000. Plant diversity increases resistance to invasion in the absence of covarying extrinsic factors. *Oikos* 91: 97-108.

This paper describes field and greenhouse experiments that demonstrate that "biodiversity loss within a community can lower its resistance to invasion."

Tilman, David, and John Downing. 1994. Biodiversity and stability in grasslands. *Nature*. 367:363-365.

This 11-year study found that species-rich grassland plots provided greater resistance to a 1986-1988 drought because they were more likely to contain some drought-resistant species; and they recovered more of their pre-drought biomass within four years after the drought ended.

While set in Minnesota, the implications are broad: "Because different species are likely to perform best for particular combinations of [disturbances], the long-term stability of primary production in these and other grasslands should depend on their biodiversity. Although we do not know how the stability of other [non-grassland] ecosystems depends on biodiversity, these results lend further urgency to pleas for the conservation of biodiversity."

Vermeij, G.J. 1991. When biotas meet: understanding biotic interchange. *Science*. 253:1099-1104.

There is ample evidence that the best method of insuring that intact plant communities remain so is to provide long term protection from the types of unnatural disturbances discussed above, in other words, disturbances outside the range of natural variability for the plant community. Vermeij (1991) notes “recipient biotas become invisable after diversity has been reduced through extinction or overexploitation.” It is clear that protection of uninvaded, mature communities, as bulwarks of vegetational resistance, should be a critical objective for maintenance of historical plant communities.

Disturbance and Invasion

Baker, H.G. 1974. The evolution of weeds. *Annual Review of Ecology and Systematics* 5:1-24.

In this literature review, Herbert Baker compiled all the literature that is pertinent to an understanding of the many genetic qualities of weeds that make them ideally adapted to human activities. Baker writes that a plant is a weed, “if, in any specified geographical area, its populations grow entirely or predominantly in situations markedly disturbed by man (without, of course, being deliberately cultivated plants)” (p. 1). This early recognition that disturbance is a factor in weed invasions is critical to developing management strategies for controlling unwanted plant invaders.

Citing numerous studies going back to the 1920's, Baker found that the “use of herbicidal sprays has seriously affected roadside weeds as well as weeds in agricultural situations. The effect of their use may be the selection of one species over another--in other words, weed shifting. Dependent upon plant morphology and reproductive strategy, some plants are able to survive spraying, and thus gain a reproductive and competitive advantage. In addition, surviving individuals may become herbicide resistant over time due to the evolutionary mechanism of selection (p 16-18).

Billings, W.D. 1990. *Bromus tectorum*, a biotic cause of ecosystem impoverishment in the Great Basin. Pp. 301-322 in: Woodwell, G.M., ed. *The Earth in Transition: Patterns and Processes of Biotic Impoverishment*. Cambridge, England: Cambridge Univ. Press.

Billings has studied the Great Basin ecosystem for decades, and provides here a description of the historical vegetation of the Great Basin, followed by an account of the establishment of *Bromus tectorum* (cheat grass) via cattle and other livestock grazing and the subsequent alteration of the historical fire regime, a story well documented elsewhere and known by land managers today throughout the West. He concludes that “*Bromus tectorum* seems to have won its conquest of the sagebrush ecosystem. The only viable alternative seems to be **prevention**

of invasion. That means maintenance of the health of the ecosystems by care and vigilance” (p. 321, emphasis added).

Denslow, J.S. 1985. Disturbance-mediated coexistence of species. Pp. 307-323 in: Pickett, S.T.A. and P.S. White, eds. 1985. *The Ecology of Natural Disturbance and Patch Dynamics*. Orlando, FL: Academic Press.

This volume by numerous ecologists provides a foundation for understanding the effects of disturbance, or lack of disturbance, upon the composition of native plant communities. Denslow notes here that “large-scale or frequent exotic disturbances may impose a functional homogeneity on a landscape” (p. 311), and “increased frequency and intensity, for example, through agricultural activity, often brings with it both the invasion of exotic weedy species which are better adapted to the new situation than are local species, and the local extinction of species unable to compensate for high mortality rates” (p. 313-314). The author stresses the importance of maintaining the evolutionarily historical disturbance regime in order to maintain species integrity: “Clearly, the extent and nature of the disturbance and the degree to which it mimics an indigenous one strongly influence the rate of return to the original community structure” (p. 317).

In another paper (Denslow 1980; *Oecologia*) he made basically the same point, arguing that communities will be most rich in species adapted to growth and establishment in the spatially most common patch types. This suggests right away that attempts to eliminate weed invasions will not be successful unless we stop creating more weed habitat or patch types.

Thus it is necessary to eliminate disturbance factors that are out of the range of natural variability for the indigenous flora, if native species are to be restored to the plant community, and to maintain and restore indigenous disturbance regimes.

Hobbs, Richard J. 1989. The Nature and Effects of Disturbance Relative to Invasions. In Drake, J.A., H.A. Mooney, et al. eds. *Biological Invasions: A Global Perspective*. Chichester, NY: Wiley.

This study is one of many possible examples of why the BLM needs, with any of its vegetation treatments, to provide matched, untreated control plots. Hobbs describes a study he carried out in each of five western Australian shrub and woodland communities. To the two halves of one meter square plots, he added 100 *Avena fatua* (an annual grass) and 100 *Ursina anthemoides* (an annual forb). To random plots he then added 50 grams complete fertilizer and/or disturbed the soil to a depth of 5cm, by breaking the soil crust and turning the soil.

The results of his experiment were “remarkably consistent across all communities”, with establishment of *Avena* greatly enhanced by disturbance in all communities, while nutrient addition on its own having little effect. Thus, simple physical disturbance of the soil was enough to greatly increase population densities of the exotic annual grass.

“In this chapter I take the view that the invasion process requires not only the availability of an invading species able to disperse into an area but also the formation of a patch suitable for colonization.” (p. 391)

“Successful invasion of a natural community requires dispersal, establishment and subsequent persistence. In most reserves in the Western Australian wheatbelt, dispersal is not the process limiting invasion since most areas receive propagules, as evidenced by the presence of other non-native species in the treatment plots.” (p. 399).

Hobbs, R.J. and S.E. Humphries. 1995. An integrated approach to the ecology and management of plant invasions. *Conservation Biology* 9(4): 761-770.

This article encourages an ecological approach to invasive species. "A focus on the invaded ecosystem and its management, rather than on the invader, is likely to be more effective." It also stresses the human contribution to invasive species problems. "Much of the plant invasion problem stems from socioeconomic rather than ecological factors. Attempts to treat weed invasion will fail unless the underlying causes of the problem are identified and dealt with."

Knick, S.T, J.T. Rotenberry, and B.Van Horne. 1999. Effects of disturbance on shrubsteppe habitats and raptor prey in the Snake River Birds of Prey National Conservation Area, Idaho. Sagebrush-steppe ecosystems symposium, Boise State University, Boise, Idaho. June 21-23, 1999. . Boise, ID: Bureau of Land Management, Idaho State office.

Combined disturbances from wildfires, military training, and livestock grazing had an additive or synergistic effect on the landscape. Regions of multiple disturbance factors experienced the greatest change in land (shrub) cover. Areas tracked by military training had more exotic annual vegetation. Burned sites had less cover of mosses, total cryptobiotic crusts, shrubs, vegetation, and had greater cover of vegetation and exotic annuals.

Mack, R.N. 1986. Alien plant invasion into the Intermountain West: a case history. Pp. 191-213 in: Mooney, H.A. and J.A. Drake, eds., *Ecology of Biological Invasions of North America and Hawaii*. New York: Springer-Verlag.

From another classic work on biological invasions, Richard Mack’s contribution to our understanding of the transformation of the sagebrush plant community of the Intermountain Region is fundamental to management of the area. In this case history, Mack chronicles the establishment of cheat grass and other invasive weeds primarily via “tillage and livestock,” and notes that “Such events are directly tied to human activity since the most pervasive functions of humans in communities are as agents of *dispersal and disturbance*” (p. 209, **emphasis added**). Thus, any effort to reduce the impacts of invasive non-native species and to restore these ecosystems must address both of these factors and mitigate them.

Grazing and Invasion

(Papers referenced in this section are separated into two groups, the first of which addresses the evidence that native plants in many ecosystems west of the Rockies are particularly vulnerable to grazing, and the second of which provide evidence that grazing often increases the abundance of exotic plants in a community.)

Grazing effects on native plant populations

Belsky, AJ. 1986. Does herbivory benefit plants? A review of the evidence. *The American Naturalist* 127(6):870-892.

This review delineates the various effects which have been claimed as possible "benefits" to plants of being grazed, and examines the evidence for the claims. Such effects include effects on shoot dry weight in a natural system; tiller production; seed size and number; plant longevity; grassland communities; plant fitness; and plant physiological processes.

Basically, the evidence is lacking for any benefit, other than in a few plants that "had been genetically improved and...were growing in fields that were irrigated, fertilized, and weeded" (p. 883), (i.e., not Intermountain West native grasslands.) Most of the few studies that have reported any increased yields following grazing, were examining only shoot dry weight, "...which is not a measure of plant productivity since a large portion of the biomass of most terrestrial plants is belowground" (p. 883).

The following unlikely set of conditions would have to be met if increased productivity were to occur in native grasslands: "The herbivores would have to maintain a species at, or only slightly below or above its optimum leaf-area index [citation]; nutrients and water would have to be adequate for regrowth; herbivory would have to occur early enough in the growing season for the plants to recover; and no other species could be in a position to gain a competitive advantage" (p. 885).

"Conclusions about increased fitness of individual species based on their productivity in multispecies communities must also be carefully scrutinized. In communities with more than one species, removal of plant tissue alters competitive relationships, inhibits succession, changes species composition, and initiates population turnover. Any one of these factors could stimulate the growth of some species but inhibit the growth of others" (p. 885).

[Note: While this article is technical, and breaks down plant "benefits" into specific responses, there is no other way to examine closely whether the often thoughtlessly-rendered opinion that "grasses need grazing" has a good scientific basis behind it. And the answer basically is, no.]

Burkhardt, Wayne. 1994. Herbivory in the Intermountain West: An overview of evolutionary history, historic cultural impacts and lessons from the past. Paper prepared for Interior Columbia Basin Ecosystem Management Project.

AND

Painter, Elizabeth. 1994. Comments on two papers by Wayne Burkhardt: "Herbivory in the Intermountain West: An Overview of Evolutionary History, Historic Cultural Impacts, and Lessons from the Past," and "Paleoecological Relationships of Prehistoric Equus in the Intermountain West" An Overview with Implications for Management of Wild Horses and Burros." Review requested by Interior Columbia Basin Ecosystem Management Project.

Painter's documented review systematically dismantles the various non-mainstream, ill-documented contentions of Burkhardt that bison were present in large numbers in the Intermountain West, and that the native vegetation there has adapted to and benefits from grazing by their functional equivalent, livestock.

It is a long review, 29 pages of small-font text, and 12 pages of references, but it is worth paying attention to, because she points out, in turn, the following:

- (1) The lack of evidence (and paleobotanical and paleoecological evidence to the contrary) for Burkhardt's claim that large herbivores were present in large herds in the Intermountain West;
- (2) The same for Burkhardt's cliché-driven implications that plants benefit from being grazed;
- (3) The same for Burkhardt's claim that domestic livestock and Pleistocene mega-fauna are functionally equivalent;
- (4) The same for Burkhardt's contention that breaking up the "soil surface crusts which are so common to Intermountain soils" is beneficial.

Ultimately, Painter points out that public land agency acceptance of scientifically unsubstantiated opinions such as Burkhardt's "...can leave public-land management agencies and their personnel vulnerable to accusations of 'management by myth'" (p. 29).

Caldwell, M.M., J.H. Richards, D.A. Johnson, R.S. Nowak, and R.S. Dzurec. 1981. Coping with herbivory: photosynthetic capacity and resource allocation in two semiarid *Agropyron* bunchgrasses. *Oecologia* 50: 14-24.

This paper is important because it so clearly describes WHICH CHARACTERISTICS make blue-bunch wheatgrass, which evolved under a history of light grazing pressure, intolerant of grazing.

The paper compares the response to clipping of *Agropyron spicatum*, the once dominant bunchgrass of the Intermountain west, with *Agropyron desertorum*, a

congener that evolved on the Eurasian steppe, with a history of heavy large herbivore pressure.

A field experiment was conducted on 7,000 bunchgrasses of the two species, planted two years previously in a matrix of sagebrush, to approximate a natural competitive environment. The grasses were clipped on April 30 to remove 80% of their tissue, and then two weeks later to remove 90% of regrowth.

Following defoliation, *A. desertorum* re-established photosynthetic area much more quickly than did bluebunch wheatgrass, even though the plants were of similar size. Soon, the canopy of *A. desertorum* was 3-5 times larger than that of its congener.

While *A. desertorum* responds to defoliation by shifting its resource allocation to shoots and leaves (presumably a response to its evolutionary familiarity with grazing), *A. spicatum* lacks that flexibility. Instead, it continues to add root tissue as rapidly after defoliation as before – a likely maladaptive response when what is lacking is not water and nutrients, but photosynthetic tissue. (One speculative thought is that *A. spicatum*, relatively naïve with regards to grazing (but not to drought) interprets the stress produced by defoliation as resulting from belowground rather than aboveground deficits.)

In any case, the response clearly has served *A. spicatum* poorly of late in a region that has seen such an increase in the frequency of defoliations.

Mack, Richard N. and John N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. *The American Naturalist*. 119: 757-773.

Mack and Thompson (along with Milchunas and Lauenroth – see references in this section) are grassland biologists who were impressed by the “striking susceptibility” of Intermountain grasslands to grazing by domestic livestock, and to invasion by Eurasian exotics, and asked why that might be. The fascinating evidence in this article indicate that at least for the last 2500 years, and likely for longer, Intermountain grasslands have lacked the herds of large herbivores that were so common on the Great Plains. As a result, the native grasses lack adaptations to grazing. Under pressure from livestock, they are poorly equipped to compete with invasive exotics that have in many cases evolved for thousands of years with the very same domestic livestock that now roam the west.

Table 1, on page 760 lists some of the characteristics (including sensitivity to clipping, caespitose habit, high flowering/vegetative culm ratio, weak culms, shallow seedling root depth, and early phenology) that make several of the region’s dominant perennial grasses sensitive to grazing.

“temperate grasslands and specifically steppes differ greatly in the extent of habitation by large mammals throughout the Neogene and hence the plants in these grasslands differ in the extent to which they have traits adapted to large mammalian grazers.” (p. 757)

Milchunas, D.G., and W. K. Lauenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs* 63(4): 327-366.

The effects of livestock grazing differ depending on the ecosystem in question, and depend strongly on the evolutionary history of the species in a system, that is, whether or not they evolved to tolerate heavy grazing and trampling?) This paper is likely the most thorough examination to date of this question.

The authors begin with the observation that the effects of grazing on productivity and composition of vegetation vary widely at sites around the globe. Next, they ask what variables, both of the ecosystem-environmental variables and of the grazing regime, best explain or account for variation in the sensitivity of plant communities to grazing.

Milchunas and Lauenroth compiled a data set consisting of **236 sites** (studies) around the world to address this question. The component studies compared species composition, aboveground net primary production (ANPP), root biomass, and soil nutrients of grazed vs. ungrazed sites and included grasslands, shrublands, forests and montane plant communities. Multiple regression analyses were used to evaluate the importance of ecosystem-environmental variables (i.e., evolutionary history of grazing, precipitation, ANPP, latitude, mean high temperature of the warmest month, mean low temperature of the coldest month and temperature range) and grazing variables (i.e., grazing consumption or intensity, expressed as a % of ANPP, and duration of protection from grazing) in explaining variation in the dependent or response variables across sites. The authors looked at several grazing response variables including (a) change in species composition measured as species dissimilarity between grazed vs. ungrazed plots or sites; (b) change in the absolute abundance of the most dominant species; and (c) percent change in ANPP due to grazing.

Changes in species composition with grazing were primarily a function of ANPP and the evolutionary history of grazing of the site, with level of consumption (i.e., grazing intensity) coming in third in importance. That is, the greatest changes in species composition occurred at humid, productive sites with a long evolutionary history of grazing and where current grazing intensity was high. These 3 variables explained > 50% of the variation in species composition change in grassland and shrubland communities. Duration of grazing (i.e., years of protection) was significant only when the analysis was restricted to shrubland communities. Furthermore for all communities, grasslands and shrublands together, and grasslands alone, compositional changes were more sensitive to changes in ANPP and evolutionary history than to changes in grazing intensity. The greater importance of ecosystem-environmental variables compared to grazing variables in sensitivity analyses suggests that **in terms of grazing impacts, where we graze (i.e., geographical location) may be more important than how we graze (intensity and duration) at least within levels not considered to be extreme overgrazing.**

[NOTE: This point is of critical importance for landscape-level planning of appropriate land management to prevent and minimize invasions (favor native and not exotic species). The implications of this study are the same as those stated by Mack and Thompson (1982) more than a decade earlier—that grasslands,

shrublands, and woodlands of the Intermountain West may be more vulnerable to livestock disturbance and exotic plant invasion than other regions of the United States, such as the Great Plains. For thousands of years prior to the arrival of livestock, native herbivores such as deer, elk, and pronghorn are thought to have been too sparse to exert strong selective pressures on native grasses and broadleaved herbaceous species (also see Mack 1989; Miller et al. 1994). Thus, the introduction of domestic livestock in the 1800's added a new type of perturbation to these western ecosystems (Mack & Thompson 1982, also see Schiffman 1997). **It is critical that BLM's guidelines for weed management take into account the evolutionary history of the system in question and do its best to ensure that management maintains the environmental conditions that favor native and not exotic species.]**

Similarly, evolutionary history, precipitation, low temperature, and grazing intensity were the most important variables in explaining variation in the change in abundance of the most dominant species at grazed vs. ungrazed sites. Again, ecosystem-environmental variables were more important in sensitivity analyses than grazing variables. Increases in the dominant species occurred under conditions of short evolutionary history-low consumption and large decreases occurred under conditions of short evolutionary history-high consumption, regardless of the level of ANPP. Seventy-seven percent of the sites had dominant species decreasing with grazing; bunchgrasses showed the greatest decreases (mean = - 43%) while shrubs increased on average (mean = + 18%); the latter supports the view of grazing as a factor in the conversion of grasslands to shrublands.

Percentage differences in ANPP between grazed and ungrazed sites decreased with longer evolutionary histories of grazing and increased with increases in ANPP, in levels of consumption and in duration (years) of treatment. For grasslands plus shrublands evolutionary history accounted for 59% of the variation in the percent difference in ANPP due to grazing. Most of the differences in ANPP due to grazing were negative (83%) although models for grasslands plus shrublands predicted positive increases in ANPP with grazing (17% of all cases) under conditions of long evolutionary history of grazing, low ANPP, low consumption and short duration of current grazing. These data and models support the hypothesis that we dealt with in Grazing 2, the herbivore optimization hypothesis, which states that herbivores (and herbivory) can increase overall productivity. This study puts the hypothesis in perspective by identifying the ecosystem-environmental conditions that confer resistance to livestock grazing.

The authors conclude that (1) assessments of grazing impacts must be multivariate and include both aboveground and below-ground components; and (2) that management decisions based on observed changes in species composition due to grazing may lead to incorrect conclusions on the long-term ability of the system to sustain productivity.

Naveh, Z. and R.H. Whittaker. 1979. Structural and floristic diversity of shrublands and woodlands in Northern Israel and other Mediterranean areas. *Vegetatio* 41(3):171-190.

In this paper, Naveh and Whittaker compare similar Mediterranean habitats in Africa, California, Israel, and Chile. They found that high grazing pressure on American range lands results in reduced native species diversity because native species here are not adapted to high grazing pressure, while European species have a long association with human beings and a shared evolutionary history under “constant stress from drought, fire, and grazing” (p. 183). Thus, when European plants from these environments are introduced to America, they arrive pre-adapted to the conditions associated with heavy grazing and other types of human disturbance, while native species are not. Increasing severe grazing also results in limiting the number of species that can survive to “a few most aggressive and unpalatable ones” (p. 183).

Young, J.A. 1994. History and use of semi-arid plant communities – changes in vegetation. p. 5-8 in S.B. Monsen and S.G. Kitchen, eds. *Proceedings: Ecology and Management of Annual Rangelands*. USDA Forest Service General Technical Report. INT-GTR-313. Intermountain Research Station. Ogden, UT.

The biological vacuum caused by livestock grazing removal of understory vegetation was filled by cheatgrass, which dominates sites and truncates plant succession.

Grazing effects on invasive exotic populations

Anderson, J. E., and R. S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. *Ecological Monographs*. 71:531-556.

In this outstandingly executed long-term study, Anderson and Inouye document the remarkable recovery of native bunchgrasses and sagebrush following 45 years of livestock exclusion in Idaho.

The authors emphasize that the health, vigor, and dominance (cover) of native species, though not native diversity, is critical for maintaining resistance to invasion: “abundance of non-native species was negatively correlated with cover, but not richness of native species.”

The long-term nature of the study provided the authors with a data set that allowed them to see how “drought and grazing have similar, synergistic effects. Widespread local extinctions due to either cause would tend to homogenize vegetation across the landscape.” (p. 545)

The authors suggest that recovery following livestock removal is possible if residual populations of native species are present:

“the...probably more important reason for the observed changes at the INEEL is that viable remnant populations of native grasses and forbs were present in 1950 and were able to take advantage of improved growing conditions. Indeed, a few other studies have shown that arid and semiarid communities can respond to reduced stocking rates and favorable precipitation with increased production of native perennial grasses and forbs if residual populations of such natives are present (Robertson 1971, Turner 1990, Holecheck et al. 1994).” (p. 548)

In addition, the authors found that cover of native species increased resistance of the vegetation to invasion:

“The density of nonnative species was negatively correlated with total cover of native shrubs and perennial grasses in three of seven sample years.” (p. 543)

“The 1995 point frame data indicate that cover of *B. tectorum* is strongly inhibited by cover of native species. Studies of postfire vegetation on areas burned recently by wildfire show that invasion by exotic species is severely limited on areas where perennial grasses and forbs resprout in abundance.” (p. 553)

“[A]dequate cover of native species can render these semiarid communities more resistant to invasion. Maintaining richness and cover of native species should be a high management priority for these ecosystems” (from the abstract)

“Good cover of perennial species in sagebrush steppe appears to increase resistance to invasion.” (p. 552)

[Note: The question of whether livestock removal can result in recovery of invaded or otherwise degraded high desert ecosystems is a point of controversy, as in many sites, livestock removal results in native recovery, but in others, little recovery. One hypothesis proposes that once a sagebrush/bunchgrass system is disturbed beyond a “threshold”, it will not recover, even following livestock removal. Others point to climate as a more important determinant of recovery, though the answer likely lies somewhere in between: recovery cannot occur without livestock removal or otherwise dramatic improvements in livestock management to avoid favoring exotic species.]

However, recovery probably also requires optimal climatic conditions—for some native bunchgrasses, it may be more than 20 years before temperature and precipitation are optimal for the type of recruitment “pulse” needed for natives to explode and fully re-occupy a site. This may explain the numerous anecdotal reports that I (Jon Gelbard) have heard from scientists and agency personnel of native bunchgrasses failing to return for years following livestock removal, but then suddenly just “appearing” after more than 10-30 years.]

Belsky, A.J. and J.L. Gelbard. 2000. *Livestock Grazing and Weed Invasions in the Arid West*. Portland, OR: Oregon Natural Desert Association.

Belsky and Gelbard reviewed 189 scientific papers and found that livestock contribute to alien weed invasions in at least seven different ways, including:

- 1) Transporting weed seeds into uninfested sites on their coats and feet and in their guts;
- 2) Preferentially grazing native plant species over weed species;
- 3) Creating patches of bare, disturbed soils that act as weed seedbeds;
- 4) Destroying microbiotic crusts that stabilize soils and inhibit weed seed germination;
- 5) Creating patches of nitrogen-rich soils, which favor nitrogen-loving weed species;
- 6) Reducing concentrations of soil mycorrhizae required by most western native species;
- 7) Accelerating soil erosion that buries weed seeds and facilitates their germination.

The authors concluded “nonindigenous weeds will continue to spread through arid and semi-arid grasslands, shrublands, and woodlands in the western United States unless selective grazing, nutrient redistribution, and soil disturbances by livestock are greatly reduced or eliminated” (p. 3, emphasis added).

Gelbard, Jonathan, and Joy Belsky. 1997(?). Livestock grazing facilitates exotic plant invasions in rangelands of the Intermountain West, U.S.A. (Draft paper to be submitted for publication).

This review examines the scientific literature regarding some of the direct and indirect mechanisms by which livestock grazing facilitates the introduction, establishment and spread of noxious weeds: Selective grazing, trampling, destruction of microbiotic crusts, reductions in nitrogen, creation of a drier soil microenvironment, accelerated erosion, and altered fire return interval.

In addition, studies are reviewed indicating that in some cases livestock removal is itself a treatment that can restore invaded communities.

"In eastern Oregon, frequency of the exotic grass *Bromus mollis* not only decreased when protected from grazing, but increased 1.7% to 47.5% where grazing continued" (p. 15).

"In another instance, eight years of protection reduced cheatgrass cover from 4% to 1%, and reduced its frequency from 25% to 4%" (p. 15).

"In other enclosure studies, especially those involving cheatgrass, livestock removal has not been followed by the decline of exotic weeds through succession" (p. 15). Variables accounting for this are discussed. (For instance,

time since exclusion, as one pair of researchers found reductions in cheatgrass cover to occur after 30 years of livestock exclusion).

Extensive bibliography.

Jacobs, James S, and Roger L. Sheley. 1997. Relationships among Idaho fescue defoliation, soil water and spotted knapweed emergence and growth. *Journal of Range Management* 50: 258-262.

In pot experiments with two-year old Idaho fescue plants, the authors found that clipping young grass plants to simulate grazing increased the number and weight of successfully establishing spotted knapweed seeds. The young grasses were clipped one to three times, removing a total of between 30% and 90% of their biomass, knapweed seeds were applied at a rate of 5,000/m². Pots with unclipped plants had about **one** spotted knapweed per pot - those subjected to 60% defoliation averaged **four** seedlings, and 90% defoliation allowed survival of an average of **seven** knapweed plants (**Figures on p. 261**). Greater frequency of clipping also increased the level the number and weight of the invader's seedlings.

The connection between clipping and knapweed establishment seems to result from higher soil moisture content in pots with clipped grasses (which transpire less than intact plants) (**Figures 2 and 4**). A simple experiment, with simple results, and a clear message about the relation of defoliation of a dominant native plant and an aggressive exotic. Spotted knapweed already infests 2.2 million acres (**p. 258**). By the far most cost-effective (and simply effective) method of limiting its spread and density will involve preventing conditions (such as defoliation of native grasses by livestock) that favor its invasive success over millions of acres.

"Our results indicate that even moderate defoliation (30%) may allow greater spotted knapweed growth on Idaho fescue rangeland" (**p. 261**).

LeJeune, K.D., T.R. Seastedt 2001. *Centaurea* species: the forb that won the West. *Conservation Biology* 15(6):1568-1574.

The authors reviewed the literature regarding the ecology of five species in the genus *Centaurea*, (including yellow starthistle, and spotted, diffuse, squarrose, and Russian knapweeds) as well as the conditions and sources of the plants' spread and establishment in western grasslands. They found that "increased atmospheric nitrogen deposition, reduced fire frequency, and possibly, direct and indirect fertilization resulting from cattle grazing appear to have reduced the historically strong nitrogen limitation to which native species of western grasslands are adapted" (**p. 1568**). In addition, *Centaurea* species appear to be better competitors for limited phosphorus in soils. Stressing the importance of soil biogeochemistry, as well as the current and historical disturbance regimes and their effect on nutrient availability and nutrient ratios, the authors state: "Reestablishment of nitrogen limitation is critical if the traditional species composition of invaded sites is to be restored." In addition, the authors conclude:

“If the historically limiting nutrient that structured grasslands communities and interspecific competitive relationships is now no longer limiting, then traditional weed-control techniques are unlikely to restore native community composition over the long term” (p. 1573).

Olson, Bret E. 1999. Grazing and Weeds. In Sheley ed., *Biology and Management of Noxious Rangeland Weeds*. Corvallis, OR: Oregon State University Press.

By their dietary preferences alone, cattle in the West favor weedy forbs, inedible grasses, and woody plants over native grasses. That is simple biological fact – there is no way around it – and in this chapter Olson summarizes some of the evidence backing it up. Olson is a range ecologist and is concerned largely with managing land for its forage value (not for ecological restoration per se), but his approach is to address ecological reality head on.

There is of course nothing exceptional about the way he addresses causes and treatments together in the same analysis: it’s an often used technique for solving problems, not just in range management but in any area of human life. However, the way that Olson (as do so many range ecologists) addresses grazing as a cause of plant invasion, as a matter of course, is an indication that the BLM needs to as well. The philosophy expressed in his concluding paragraph, cited below, could serve well as a summary of the strategy laid out in the Restore Native Ecosystems Alternative, and needs to be addressed by the BLM in its analysis of alternatives.

“In grazed systems, inherent diet preferences have been a major force in shifting species composition of native plant communities. . . Because cattle, the dominant grazer in this system [western N. America] selectively graze native grasses and have low impact on these non-indigenous grasses and weeds, native species are at a disadvantage in competing for limited soil water and nutrients. This leads to a preponderance of weedy, undesirable species.” (p. 85)

“Weed infestations are not a problem that arrived overnight, and will not be cured overnight. Too often our most common weed control techniques address the symptom of a land management problem, not the cause. If the cause of a problem is not addressed, weeds will continue to spread. Or, if we successfully eradicate a weed, another weed will fill that niche because we have not solved the underlying problem.” (conclusion, p. 94)

Roché, Ben, Cindy Roché, and Roger Chapman. 1994. Impacts of grassland habitat on yellow starthistle (*Centaurea solstitialis* L.) invasion. *Northwest Science* 68(2):86-96.

This study examines the issue of what makes a grassland more or less susceptible to yellow starthistle invasion after introduction. [Note: It has implications for protection from livestock grazing of perennial bunchgrasses on BLM lands.]

Four species of perennial rangeland forage grasses were established in plots, and four management treatments included clipping at one of three times (May,

July, October) and no clipping, for each of three years. Each fall, yellow starthistle seeds were planted 2 cm apart between the center three rows of each plot of grasses. The number of yellow starthistle plants were then recorded during the last year.

"Clipped bunchgrasses were much more susceptible to invasion than the sod-forming grasses. Yellow starthistle was particularly successful in spring or fall clipped Whitmar bluebunch wheatgrass" (p. 93).

Tu, M., C. Hurd, and J.M. Randall. 2001. Weed control methods handbook: tools and techniques for use in natural areas. Wildland Invasive Species Program, The Nature Conservancy. 2 April 2001.

These authors address the feasibility of using livestock to control weeds:

"Grazing should be closely monitored and the animals promptly removed when the proper amount of control has been achieved an/or before desirable native species are impacted. Consequently, land managers must be flexible and have control over herd movements. **Lack of control can result in overgrazing of desirable species, which can enhance weed infestations or allow new weed species to become established. The necessary flexibility is not always possible with commercial herds.**" (p. 23).

Microbiotic Crusts and Invasion

Anderson, David, KT Harper, and SR Rushforth. 1982. Recovery of cryptogamic soil crusts from grazing on Utah winter rangers. *Journal of Range Management* 35(3):355-359.

A study of eleven livestock exclosures in cool desert shrub communities in Utah to determine rate of microbiotic crust reestablishment when livestock are excluded.

While vascular plant cover (i.e., grasses, forbs) did not differ significantly inside and outside the exclosures, "Grazed areas supported only one-tenth as much moss cover, one-third as much lichen cover and about one-half as much algal cover as did the areas within exclosures" (p. 357).

As for recovery, "A sharp increase can be seen in cryptogamic and algal cover after a period of from 14 to 18 years of protection from grazing. The 20-year span following this initial period of recovery shows only a slight increase in cryptogamic and algal cover. Apparently, the crust is almost fully recovered from grazing in a period of less than 18 years" (p. 358).

The number of lichen species continue to increase through the entire 37-38 years of exclosure time available.

Also, this is yet another article that demonstrates the importance of leaving some BLM lands unexploited, if only for their scientific value as reference areas for determining the effect of different treatments. In this case, the authors indicate that: "Since we know of no exclosure in Utah semideserts that are younger than about 15 years, we have no way of knowing the shape of the recovery curve of cryptogamic crusts for the interval between 1 and 15 years" (p. 359)

The use of untreated controls is a fundamental of experimental design: it is in many cases absolutely essential to distinguishing a treatment's effects from effects resulting from other causes.

Belnap, Jayne. 1993. Recovery rates of cryptobiotic crusts: inoculant use and assessment methods. *Great Basin Naturalist* 53: 89-95.

This paper indicates that in Utah, recovery of cryptobiotic crusts is very slow, taking between 30 and 85 years depending on the site and on the measurement of recovery that is used.

Belnap performed experiments at four sites near Moab, Utah, in which inoculant was used to attempt to restore biotic crusts to areas from which it had been completely removed. Although inoculated plots initiated biological recovery faster than uninoculated plots, recovery was slow on all plots.

She found that though visual assessment gave an impression of quick recovery, measurements of chlorophyll a levels, lichen growth, and cyanobacterial sheath extension show that complete recovery is much slower (40 years for chlorophyll a levels, 30-65 years for cyanobacterial sheath depth, and 45-85 years for lichen cover). (p. 94)

"Visual assessment as a means of determining crust recovery proved to be misleading. All plot surfaces, whether inoculated or not, appeared completely covered by cyanobacteria, and most showed rudimentary pediceling after only one year. . . Chlorophyll a measurements, however, told a different story" (p. 93)

"This study demonstrates that recovery can take a long time, especially for lichen and moss components of cryptobiotic crusts. For this reason, **a conservative approach should be adopted relative to activities that may disturb these crusts.**" (p. 94)

Stohlgren, T. J., Y. Otsuki, C. A. Villa, M. Lee and J. Belnap. 2001. Patterns of plant invasions: A case example in native species hotspots and rare habitats. *Biological Invasions* 3: 37-50.

The authors examined patterns of native and exotic species diversity at multiple spatial scales and in multiple plant community types in Grand Staircase Escalante National Monument, which is managed by BLM.

The authors found that **both the number and cover of exotic species were strongly negatively correlated with biological soil crust cover.**

They suggested that the crusts act as physical barriers to exotic seed germination, establishment, and growth by preventing their seeds or radicles from contacting mineral soil, i.e., preempting space.

The authors concluded that continued disturbance of crusts by livestock, people, and vehicles may facilitate further exotic plant invasions.

Belnap, J., and O.L. Lange. 2001. *Biological soil crusts: structure, function and management.* Berlin: Springer-Verlag.

A wonderful summary of current knowledge concerning the ecology and management of biological soil crusts by the leading expert (i.e., Belnap) on the subject.

The authors provide a list of guidelines for land management to prevent the destruction of biological soil crusts, including avoiding grazing livestock in areas containing healthy crusts except during times that native grazers historically grazed these sites (winter). During winter, the crusts are wet, covered with snow, or otherwise not brittle and thus less highly sensitive to disturbance. The presence of moisture also allows crusts to re-establish before the onset of summer drought. A note of warning is that the resilience of wet soils does not apply to clayey soils, where alterations to microtopography caused by livestock hooves can last for years, if not decades. The authors emphasized the importance of not grazing livestock in areas containing healthy biological soil crusts when the crusts are dry.

Gelbard, J.L. and J. Belnap. Roads as conduits for exotic plant invasions in a semi-arid landscape. Peer reviewed, revised, and re-submitted. *Conservation Biology.*

When using statistical tests that accounted for environmental differences among sites, there was a significant tendency for exotic species to be less prevalent on sites containing greater biological soil crust cover.

Biological soil crust cover was negatively correlated with exotic species richness and the cover of *Bromus tectorum* and *Salsola iberica*, but positively correlated with native species richness and the cover of *Stipa (Hesperostipa) comata*.

Gelbard and Belnap state that: "This relationship may indicate a direct facilitation of natives, and exclusion of non-natives, by biological soil crusts. In addition, because biological soil crusts are readily destroyed by trampling or vehicles, they can be used as a surrogate measure for soil surface disturbance. As such, they suggest a positive relationship between soil surface disturbance and exotic species richness and cover, and a negative relationship between disturbance and native richness and cover."

They continue that, "These findings agree with Stohlgren et al. (2001), who observed strong inverse correlation between exotic species richness and cover

of biological soil crust. One implication of this finding is that plant communities near roads with more disturbance and/or less biological soil crust cover are more vulnerable to invasions. Another implication is that biological soil crusts may act as a physical or chemical barrier to the establishment and growth of some exotic species, and in turn may help protect native species (Mack 1989; Kaltenecker et al. 1999; Belnap et al. 2001; Stohlgren et al. 2001)."

The authors specify that: "As with the effect of road improvement, our findings suggest that these effects may be most pronounced in communities that are sufficiently invasible to allow exotic invaders to establish, spread, and suppress native reproduction (Harris 1967, Billings 1990) or alter ecosystem processes (Billings 1990, BLM 1999)."

Johnston, Roxanna. 1997. *Introduction to Microbiotic Crusts.* Washington, DC: Grazing Lands Technology Institute, Natural Resources Conservation Service, U.S. Department of Agriculture.

This USDA publication explains the nature of microbiotic crust on western U.S. lands, including characteristics, formation (including successional changes in composition), and functions (eg., contributions to soil stability, nutrient relations, water relations, infiltration, and plant germination and growth).

"Full recovery of microbiotic crusts from disturbances is a slow process, particularly for mosses and lichens" (p. 9).

"More studies are needed, especially those that expand into other ecological regions" (p. 10).

Leonard, Stephen, Roger Rosentreter, and Michael Karl. 1995. *Microbiotic Crusts: Ecological Roles and Implications for Rangeland Management in the Interior Columbia Basin and Portions of the Klamath and Great Basin.* Review draft. Walla Walla, WA; Range Task Group, Science Integration Team, Interior Columbia Basin Ecosystem Management Project.

This review is primarily a literature review, but is informed as well by "years of observation," (e.g., by author Roger Rosentreter). This is a particularly useful review, because it has been compiled to glean what is relevant, or may be relevant, to the Interior Columbia River Basin.

"Widespread recognition of the potential roles, functions and management of microbiotic crusts is a fairly recent phenomenon and research is limited, particularly within the Columbia Basin" (p. 1; **emphasis added**).

"...consensus in the U.S. is that land use by large ungulates (livestock or wildlife) results in negative impacts on the crusts" (p. 9)

[Note, however, that crusts had survived for thousands of years in the presence of wild ungulates; and have been visibly and obviously degraded in most livestock-grazed areas. Mary O'Brien was struck by this once while backpacking

in Arches National Park, where occasional deer prints could be seen in the crust, but the crust is pulverized and/or absent outside the Park in the same region and soils.]

Management recommendations for livestock grazing are included, but they are generally confusing, or infeasible, and/or unreferenced as to demonstrated efficacy at protecting crusts. For instance, it is noted that "Removal of livestock before early spring allows reformation of crust structure during this time of optimal growth conditions without further disturbance." [This is presumably related to grazing where there is snow and ice, as noted in the Memmot (1995) chapter that follows this: "During the winter months, crusts are may be [sic; sounds like Memmot wasn't sure!] protected by frozen soil and snow cover which appears to minimize the crushing and cutting hoof action of cattle" (p. 33 in Memmot)] So where do cattle go after "early spring"? The recommendation continues: "Muddy conditions during this period should also be avoided" [How?]

Another recommendation, without any reference as to its on-the-ground outcome: "Dispersal of livestock throughout useable portions of pastures rather than concentration for 'herd effect' should be emphasized" (p. 11) [Where has this been done and monitored, and what were the results?]

[Note: One has to wonder about the realism of these recommendations when Burkhardt's discredited and unscientific account of native herbivores (see Elizabeth Painter's critique above in the section, "Grazing effects on native plant populations") is cited for "winter grazing most closely replicates the grazing strategy of native herbivores" p. 11. Any recommendations should be attempted and monitored within active allotments, rather than risk the destruction of recovering crusts in vacant allotments, given the documented evidence on impacts of livestock on crusts and lack of evidence to the contrary.]

"Grazing management objectives should include desired levels of microbiotic crust based on site capability and rangeland health indicators of site stability and nutrient cycling...[I]nitial estimates can be determined by using comparison areas [e.g., vacant allotments] determined to be in 'healthy condition'" (p. 13).

"Protect relic sites as rangeland reference areas. Avoidance [of livestock grazing] might be most appropriate for some sites such as...relic areas in high ecological condition that provide intrinsic value as comparison areas for ecological potential and for future scientific research" (p. 12).

Mack, Richard, and John Thompson. 1982. Evolution in steppe with few large, hooved mammals. *American Naturalist* 119:757-773.

The classic paper indicating that the grasslands west of the Rockies (i.e., dominated by C3 caespitose grasses and microbiotic crusts) evolved with little pressure from large ungulates and are not resilient to livestock grazing.

Regarding the microbiotic crust portion of these grasslands: "In communities elsewhere in which cryptogam cover is extensive these slow-growing organisms respond adversely to regular grazing by large animals [citations].. Presence of

large ungulates even at low density in the *Agropyron* Province [wheatgrass-dominated] results in rapid, permanent loss of cryptogams through trampling [citations]. In turn the broken cryptogam crust is a major source of microsites for alien grass establishment. Prior to domestic livestock introduction common ungulates were small (e.g., pronghorn antelope versus cow/bison, 70 vs. 500 kg) and/or present in low numbers; their localized trampling damage could be tolerated even by communities ill-equipped to cope with such disturbance. It appears that herbivorous mammals are incompatible with maintenance of steppe where cryptogams (particularly crustose lichens) occupy a significant fraction of the soil surface" (p. 764).

Memmott, Kelly. 1995. Seasonal grazing impact on cryptogamic crusts. Chapter Two in: *Seasonal Dynamics of Forage Shrub Nutrients and Seasonal Grazing Impact on Cryptogamic Crusts*. Masters thesis, Department of Botany and Range Science, Brigham Young University, Provo, UT.

Chapter Two describes a short-term study of a south-central Idaho study of crested wheatgrass plots (not clear how many), each of which had been recently sprayed with 2,4-D and tilled and planted with five species of shrubs after many years of heavy grazing. Two to four years later, each plot was divided into a 0.4 ha, non-grazed area, and three 1.2 ha pastures. Each 1.2 ha subplot was grazed either in spring, summer, or winter.

Results: "Cryptogamic cover in the grazing treatments was dominated by mosses" but moss dominance decreased as total cover of cryptogams increased. "Basal cover of perennial grasses was significantly higher under winter grazing and on control plots than under spring and summer grazing treatments" (p. 32).

"Spring grazing was found to have the most destructive impact on the cryptogamic crusts... Summer grazing had a slightly less negative impact...but it still reduced cryptogamic cover by nearly 37% relative to winter grazing" (p. 33)

"Black lichens, the only known nitrogen fixers among the cryptogams found in the study area, were found to be four times more prevalent in areas grazed only in winter relative to areas grazed in spring and summer" (p. 33).

Roads and Invasion

Amor, R.L., and P.L. Stevens. 1976. Spread of weeds from a roadside into sclerophyll forests at Dartmouth, Australia. *Weed Research* 16:111-118.

Measured the extent to which alien plants have spread from an old roadside into three sclerophyll forest communities in Australia.

The frequency of alien plants in the forests decline with increasing distance from the road, and was correlated with the reduction in diffuse light. Wetter

communities were more heavily colonized than drier communities. Species included *Hypochaeris radicata*, which is included in some of our weed lists and is certainly a problem on BLM lands.

What makes this study interesting is that 25 years later, studies continue to show the same patterns as this very early exploration of the relationship between roads and the spread of exotic plants. For example, a study by **Parendes and Jones in Conservation Biology, Feb. 2000**, observed similar patterns in Oregon—in forests, sites near roads were more invaded than interior forests, especially where roads increased understory light availability. During work in Oregon surveying BLM roads (McKenzie Resource district) for noxious weeds in 1996, I (Jon Gelbard) consistently observed such patterns—weeds mainly along roads, in addition to in clear-cuts and powerline corridors.

Forman, R. T. T., and L. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* **29**:207-231.

This is the first in an outstanding series of papers by Forman exploring roads and their ecological effects. Follow-up papers appeared in the February 2000 issue of *Conservation Biology*, which contained a special feature on roads.

Here, the authors talk about the “roadside” or “verge” as the “more or less intensively managed strip, usually dominated by herbaceous vegetation, adjacent to a road surface. Plants on this strip tend to grow rapidly with ample light and with moisture from road drainage.” Page 210

“Disturbance-tolerant species predominate, especially with intensive management, adjacent to highways, and **exotic species typically are common. Roadside mowing tends to both reduce plant species richness and favor exotic plants.**”

Frenkel, R.E. 1970. Ruderal vegetation along some California roadsides. *Univ. Calif. Publ. Geog.* 20:1-163.

This classic reference characterizes the weedy vegetation associated with roads, termed ruderal vegetation. Frenkel notes that the “alien component in the roadside flora decreased with distance from centers of human activity” and “critical to the establishment of ruderals is the existence of points of persistent disturbance and introduction such as cattle corrals, resorts, and highly disturbed roadsides” (p. 139). In regards to herbicide use, Frenkel found that 2,4-D reduces the percentage of dicotyledons, thus favoring grasses, and that some plants are resistant or become so (p. 135).

Gelbard, J.L. and J. Belnap. 2001. Peer reviewed, revised, and resubmitted, *Conservation Biology*. Roads as conduits for exotic plant invasions in a semiarid landscape.

The authors measured the cover of exotic and native species in roadside verges and both the richness and cover of exotic and native species in adjacent interior communities (50 m beyond the edge of the roadcut) along 42 roads stratified by the level of road improvement (paved, improved surface, graded, and four-wheel-drive track). **Sites included both Canyonlands and Arches National Park, and BLM lands outside these parks.**

In roadside verges along paved roads, the cover of *Bromus tectorum* was three times as great (27%) as in verges along four-wheel-drive tracks (9%).

The cover of five common exotic forb species tended to be lower in verges along four-wheel-drive tracks than in verges along more improved roads.

Richness and cover of exotic species were both more than 50% greater, and richness of native species was 30% lower, at interior sites adjacent to paved roads than adjacent to four-wheel-drive tracks.

Environmental variables relating to dominant vegetation/plant community type, disturbance to biological soil crusts, and topography were significantly correlated with exotic and native species richness and cover. In other words, 1) community types characterized by deep, silty, or otherwise fertile soils were more invaded than those characterized by shallow, coarse, or otherwise infertile soils; 2) communities with disturbed biological soil crusts tended to be more invaded than communities with undisturbed crusts; and 3) communities located on steep slopes tended to be less invaded than communities in flatter sites, possibly for reasons related to soils.

“Improved roads can act as conduits for invasion of adjacent ecosystems by converting natural habitats to those highly vulnerable to invasion. However, variation in dominant vegetation, soil moisture, nutrient levels, soil depth, disturbance, and topography may render interior communities differentially susceptible to invasions originating from roadside verges. Plant communities that are both physically invasible (e.g., characterized by deep or fertile soils) and disturbed appear most vulnerable.”

The authors conclude: **We have demonstrated that as roads are improved from four-wheel-drive tracks to paved roads, the verges adjacent to them tend to become wider and to contain an increasing cover of exotic plant species. Each step of road improvement would appear to convert an increasing area of natural habitat to roadside habitat, a finding with considerable implications when extrapolated to the landscape scale.** For example, our results suggest that improving 10 km of four-wheel-drive tracks to paved roads converts an average of 12.4 ha of interior habitat to roadside plant communities that typically contain a substantially greater richness and cover of exotic species than the habitat that they replace as land cover. **The 117,205 km of rural paved roads in the state of Utah alone (U.S. Department of**

Transportation 1999) may have already converted as much as 164,087 ha of land from interior to roadside plant communities. Thus, road improvement can be considered a major agent of land-cover change that converts natural habitats to roadside habitats that tend to be highly invaded and may act as conduits for invasion of adjacent interior ecosystems (Tyser & Worley 1992; Forman 2000).

Knops, J. M. H., J. R. Griffin, and A. C. Royalty. 1995. Introduced and native plants of the Hastings reservation, central coastal California: a comparison. *Biological Conservation* 7:115-123.

The authors, distinguished experts in the ecology of California grasslands, examine patterns of native and exotic plant diversity in the outer Coast Range of Northern California and find that, **“the highest percentage of introduced species is found in disturbed areas (40%) such as roadsides...”**

“This reinforces anecdotal evidence that humans are the main cause of, intentional or accidental, (exotic plant) dispersal into this reservation and that the most likely habitats of first establishment are the disturbed areas around houses and roads.”

Lacey, C.A., J.R. Lacey, P.K. Fay, J.M. Story and D.L. Zamora. 1992. *Controlling Knapweed on Montana Rangeland*. Montana State University Extension Service C.311

"Knapweed plants are often caught in the undercarriage of recreational vehicles, ranch machinery, trains and logging equipment. Vehicles driven several feet through a knapweed site can pick up nearly two thousand seeds, 10 percent of which may still be attached to the vehicle after 10 miles of driving. Thus, seed can be spread rapidly over hundreds of miles. Off-road vehicles also damage existing vegetation and disturb the soil surface, making it easier for knapweed to invade."

"Spotted knapweed is adapted to a wide variety of environmental conditions in Montana. Plants have been observed from 1,900 feet to over 10,000 feet in elevation. The establishment of spotted knapweed is enhanced more by soil disturbance than soil property." (p. 4-5)

Londsdales, W. M., and L. A. Lane. 1994. Tourist vehicles as vectors of weed seeds in Kakadu National Park, northern Australia. *Biological Conservation* 69:277-283.

The authors collected seeds from 304 tourist vehicles entering this Australian National Park.

Individual cars carried up to 789 seeds and 15 species.

Weed species that were found on tourist cars occurred at 3 times as many sites in the Park as those weed species that were not found on tourist cars.

During their sampling of tourist vehicles, the authors found 14 species not known to be present in the Park, demonstrating how roads and vehicles can introduce exotic plants into uninfested areas.

Schmidt, W. 1989. Plant dispersal by motor cars. *Vegetatio* **80**:147-152.

Samples mud from a car driving more than 15,000 km in the growing season in Europe to assess the size and nature of the car-borne flora.

From the mud, identified and counted 124 plant species with a total of 3926 seedlings

Page 152, conclusion: **“This elucidates the increase of Ruderal and the decrease of natural plant communities on sites disturbed by man and his cars all over the world.”**

Sheley, R., M. Manoukian and G. Marks. 1997. *Preventing Noxious Weed Invasion*. Montana State University Extension, MT. 9517

A discussion of weed infestation patterns in Montana.

“Noxious weed seeds are often carried along roadways in the undercarriage of vehicles. A Montana State University study showed that a vehicle driven several feet through a spotted knapweed infestation could pick up about 2,000 seeds. Only 10 percent of the weed seeds remained on the vehicle 10 miles from the infestation. Similarly, weed seeds are dispersed by machinery. It is important to remember to limit noxious weed seed dispersal by refraining from driving vehicles and machinery through weed infested areas during the seeding period. It is also important to wash the undercarriage of vehicles after driving through an area infested with a seed-producing noxious weed.” **(p. 2)**

“Noxious weeds have developed many characteristics which provide them an advantage over native North American plants in occupying disturbed soil. Minimizing disturbance of soil by vehicles, machinery, wildlife, and livestock is central to preventing noxious weed establishment.” **(p. 2-3)**

Tyser, R. W., and C. A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). *Conservation Biology* **6**:253-262.

In sites adjacent to primary and secondary roads, alien species richness declined out to the most distant transect (100 m from the road) **suggesting that alien species are successfully invading grasslands from the roadside areas.**

“The alien species richness gradients can be attributed to road-related effects.”—page 257

“While domestic grazing and anthropogenic disturbances may hasten invasion by alien species, our results suggest that dispersal from road and trail corridors into adjacent natural areas can occur even if levels of these factors are low, and perhaps even if they are absent.” (p. 259)

In a previous study (Tyser and Key 1988), roadside seed production of *Centaurea maculosa* was estimated to be about three to four times higher than in the adjacent grassland.

This study includes an exhaustive list of species present (frequency) in sites roughly 0 m, 25 m, and 100 m from paved (primary) and unpaved (secondary) roads, including the noxious weeds *Centaurea maculosa* and *Cirsium arvense*.

The authors conclude that their findings underscore “the need for alien vegetation management programs that are proactive, rather than reactive.”

Williamson, J. and S. Harrison. 2002. Biotic and abiotic limits of the spread of exotic revegetation species. *Ecological Applications* 12:40-51.

Highly disturbed sites such as roads are frequently cited as introduction points for exotic species that later spread. This paper provides evidence for 2 ideas:

- 1) When exotic species are introduced to disturbed sites, be they roadsides, campgrounds, mine tailings piles, highway rest stops, or livestock watering tanks, the introduced exotic species can spread into adjacent natural ecosystems.
- 2) The use of exotic species in revegetation treatments is very dangerous because introduced exotic species can spread into adjacent natural ecosystems.

The authors recorded all vegetation with increasing distance from sites where several non-native species were used for post-mining revegetation, and supplemented their observations with a pot experiment and a factorial field experiment.

Three exotic species showed significant declines in abundance on transects from revegetated zones into natural habitats, indicating that these species had spread into the natural habitats from revegetated zones. *Dactylis glomerata* and *Trifolium hirtum* were found up to 95 m into oak woodlands, 35 m into serpentine meadows, and up to 45 m into serpentine seeps. Interestingly, this indicates that the likelihood and degree of spread from disturbed sites such as roads differs depending on community type and soil type/fertility: “our results show that in harsh serpentine soils, the spread of recently introduced exotic species is slower than in more fertile and more invaded oak woodlands.”

The field experiment showed that *Dactylis* invasion in both oak woodland and serpentine meadow habitats was limited by disturbance and seed supply: “**disturbance and propagule addition are equally important in promoting the spread of invaders**”.

Zink, T.A. M.F. Allen, B. Heindl-Tenhunen, and E.B. Allen. 1996. The effect of a disturbance corridor on an ecological reserve. *Restoration Ecology*. 3(4): 304-310.

Assessed impact to native vegetation from disturbance and infestation of exotic competitors along a pipeline corridor in Southern California.

“Disturbances that occur as corridors into or through a protected reserve may cause much more damage by providing entry for invasion by exotic species.” (p. 304)

Fire and Invasion

Billings, W. D. 1994. Ecological impacts of cheatgrass and resultant fire on ecosystems in the western Great Basin. P. 22-30 In S.B. Monsen and S.G. Kitchen, eds. *Proceedings – Ecology and Management of Annual Rangelands*. Ogden, UT: Intermountain Research Station.

Discusses cheatgrass invasion of sagebrush and pinyon-juniper communities in the Great Basin, and vulnerability of both communities to dominance by cheatgrass following fire.

Long-term implications and cumulative effects of cheatgrass invasion: some animal and plant species in ecosystems now prone to widespread wildfires are at risk of going extinct, locally or regionally. The result will be loss of biological and genetic diversity and natural ecosystem processes. There is a genuine threat to the existence of large integrated ecosystems, with their conversion to simplistic annual grasslands –lacking many native vertebrates, invertebrates, and cryptogams that are involved in energy flow, water cycling, and nutrient balance in the ecosystem.

Cites Evans and Young (1985,1987) research where opening a juniper community resulted in colonization and domination by exotic annuals.

Harmful impacts of burning juniper: fire intensities necessary to kill juniper may result in substantial mortality of perennial native grasses, leaving sites open for weeds (Bunting 1987).

“As perennial cover, seed production, and dormant seed reserves in a site decline, annual grasses and forbs become more likely to revegetate the site

Saab, V. and N.L. Shaw. 1999. Cheatgrass expansion and biodiversity loss on the Snake River Plain, southern Idaho. Sagebrush-steppe ecosystems symposium, Boise State University, Boise, Idaho. June 21-23, 1999.

Cheatgrass competition and subsequent increases in fire frequency have contributed to further decline of native flora and fauna. Cheatgrass has now evolved adaptive ecotypes and is expanding into areas of fire disturbance. More

troublesome perennial weeds are now displacing cheatgrass over portions of its range.

USDI. 1996. Effects of military training and fire in the Snake River Birds of Prey National Conservation Area. BLM/IDANG Research Project Final Report. U.S. Geol. Surv., Biol. Res. Div., Snake River Field Station.

Documents extensive loss of native sagebrush habitat caused by fire on the Snake River Birds of Prey National Conservation Area. Also documents possible negative effects of military training and livestock grazing. Study focuses on spatial and temporal variation in habitat use by foraging raptors, and on habitat characteristics of associated prey species. Jackrabbits and Townsend's ground squirrels are adversely affected by loss of sagebrush habitat, and fire-caused conversion to annual grassland.

"Of primary concern for management of environmental stability in the NCA was the total area of shrub loss due to wildfires and the increase in the amount of highly flammable grasslands that are also susceptible to variances in precipitation." "Loss of native vegetation exceeds recovery and rehabilitation, and is exacerbated by repeated fires, military training activities, livestock use, and prevailing climate, including frequent droughts.",

"Management considerations are ... conserving existing native vegetation, reversing the predicted trend of increasing dominance by exotic plants, rehabilitation deteriorated areas, and minimizing disturbance to vegetation, prey, and raptors by land uses.

Whisenant, S.G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological management implications. Pages 4-10 in E.D. McArthur, E.M. Romney, and P.T. Tueller, eds. *Proceedings of the Symposium on Cheatgrass Invasion, Shrub Die-Off, and Other Aspects of Shrub Biology and Management*. USDA Forest Service General Technical Report, In T-276. Ogden, UT: Intermountain Research Station.

Pre-settlement fire return intervals in sage-steppe varied between 60-110 years. Cheatgrass increases fire frequencies by creating a continuous fuelbed. More frequent fires retard normal vegetation sequences. Reducing size and frequency of fires in cheatgrass-vulnerable lands should be a primary objective.

Logging and Invasion

DeFerrari, C.M. and R.J. Naiman. 1994. A multi-scale assessment of the occurrence of exotic plants on the Olympic Peninsula, Washington. *Journal of Vegetation Science* 5:247-258.

In this study in Washington State, the authors document the importance of protecting old-growth or mature conifer forests in order to resist invasion of exotic

species in forest habitats. Invasion from non-native exotic plants was found to be the highest in early seral habitats, clearcuts, and riparian corridors.

Herbicides and Exotics: Unintended Impacts

Buchmann, S.L. and G.P. Nabhan. 1997. *The Forgotten Pollinators*. Washington D.C.: Island Press.

An integral element of the Restore Native Ecosystems Alternative is the planting of native seeds and/or plants, and the protection of intact ecosystems, in order to resist further erosion of native habitats. Buchmann and Nabhan have documented the importance of pollinators to the survival of native plant communities in the western hemisphere. The authors found that “the majority of plants studied to date show evidence of natural pollinator limitation. That is to say, under natural conditions, 62 percent of some 258 kinds of plants studied in detail suffer limited fruit set from too few visits by effective pollinators.” For example, the authors note that “prairie ecologist Stephen Hendrix found extremely low seed set of three prairie wildflowers in the smallest, most isolated fragments of this remaining prairie.” When habitat patches become too small, it simply isn’t possible for native populations of pollinating insects to sustain themselves on “remnant habitat islands” (p. 24).

The authors recommend: “Pesticides and herbicides must not be sprayed in the immediate vicinity of endangered plants, rare pollinators, or their habitats. Nevertheless, the ‘spraying setback distances’ being set by the EPA and USFWS have been arbitrarily determined without detailed knowledge of specific plant/pollinator relationship...Before implementing such setbacks, on-site determinations need to be made by pollination ecologists familiar with the species involved” (p. 258-259).

DiTomaso, J.M., G.B. Kyser, S.B. Orloff, and S.F. Enloe. 2000. Integrated strategies offer site-specific control of yellow starthistle. *Calif. Ag.* 54(6): 30-36.

While examining the possible benefits of using clopyralid (Transline) to control yellow starthistle in California, the authors caution that it can also “injure most species in the legume family or Fabaceae (Leguminosae), as well as the sunflower family (Asteraceae); this may be undesirable in a control program that is trying to increase native plant diversity or enhance a threatened native plant population susceptible to the herbicide. Furthermore, continuous use of clopyralid may lead to selection for resistant biotypes of yellow starthistle or ultimately selection for other equally undesirable invasive grasses such as medusahead (*Taeniatherum caput-medusae*), ripgut brome, (*Bromus diandra*), downy brome [cheat grass] (*Bromus tectorum*), or barbed goatgrass (*Aegilops triuncialis*)” (p. 33).

Fletcher, J.S. et al. 1996. Potential impact of low levels of chlorsulfuron and other herbicides on growth and yield of nontarget plants. *Environ. Toxicol. Chem.* 15(7):1189-1196.

Fletcher, J.S. et al. 1995. Chlorsulfuron influence on garden pea reproduction. *Physiologia Plantarum* 94:261-267.

These two studies describe how extremely low exposures to sulfonylurea herbicides inhibit the reproduction of both native and crop species of plants.

Kearns, C.A., D.W. Inouye, and N.M. Waser. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. *Ann. Rev. Ecol. Syst.* 29:83-112.

In this literature review of over 233 scientific papers, the authors found that pollinator mutualisms are increasingly endangered due to fragmented habitats, changes in land use, modern agricultural practices, use of pesticides and herbicides, and invasions of non-native plants and animals. Grazing “threatens pollinators through removal of food resources, destruction of underground nests and potential nesting sites, and other more subtle mechanisms” (p. 90). Herbicide use affects pollinators by “reducing the availability of nectar plants. In some cases, herbicides appear to have a greater effect than insecticides on wild bee populations” due to the “lack of suitable nesting sites and alternative food plants.” Indeed, the role of non-native plants such as thistles in providing alternative food and host plants for pollinators in the absence of native species has not been explored and should be examined in this EIS. Some native pollinators appear to prefer non-native plants as food sources (p. 94).

This paper also describes the concerns regarding fragmentation, for pollinators. In one instance, male euglossine bees would not cross over a clearcut forested area as small as 100 m across to obtain pollen or nectar (p. 88). Other related issues from fragmentation are compounded, such as the “interactions plants have with seed dispersers and other mutualists. Loss of these interactions could lead to an extinction vortex with potentially catastrophic consequences for biodiversity” (p. 89). The authors also discuss the problem of pest or herbicide resistance, since “new chemicals must continually be developed as pests evolve resistance” (p. 97).

Wooten, George and Marlen Renwyck. 2001. *Risky Business: Invasive Species Management on National Forests – A Review and Summary of Needed Changes in Current Plans, Policies, and Programs.* Prepared for Kettle Range Conservation Group, Spokane, Washington. Report available at: <http://www.kettlerange.org/weeds/>

A great resource for land managers interested in what works and what DOESN'T work at stopping the spread of invasive weeds.

The authors looked critically at the policies and programs that the Forest Service has in place for dealing with invasives, and asked of them, one at a time, “Does it work?” and, if it doesn't, “Why not?” To track how the policies and programs

actually play out on the the ground of the National Forests, the authors focus on a series of “case studies” involving Forest Service actions and their results (very often, the opposite of what had been hoped). Finally, for each “case study” the authors propose a short list of solutions – guidelines that if followed would have likely led to better results.

The report is a wealth of ideas for how we might better deal with invasive exotics, but one message comes through most strongly of all:

“Accountability continues to plague federal land management. . . **Without clearly defined and mandatory objectives to force accountability, federal land managers have no means to assess the effectiveness or appropriateness of the actions they take.**”

At the very least, in order to learn what works, and what doesn’t, agencies must have follow-up monitoring of the effects of their treatments. One of the strengths of “Risky Business” is that it does that kind of followup, and the results that they describe are appalling. Absolutely an important document to think about.

Strategies for Control of Exotics: Biocontrol

Agriculture and Agri-Food Canada. 2000. Research Branch. Lethbridge Research Centre website: “Classical Biological Control of Weeds”.
<http://res2.agr.gc.ca/lethbridge/weedbio/index.htm>

This web site provides information about biocontrol efforts being aimed at weeds in Canada. It lists 29 invasive plants and 71 biocontrol agents that are the focus of the Canadian government’s biocontrol strategy. The website has pages devoted to many of those organisms, and gives a good sense of the level of control and specificity that can in many cases (see for example the page on leafy spurge) be achieved by the use of biocontrols.

Coombs, E.M. and G.W. Brown. 2002. *Biological Control of Weeds in Oregon: Annual Report 2001*. Pp. 18-19. Salem, OR: Oregon Department of Agriculture, Noxious Weed Control Program.

This report describes the successful biological control of yellow starthistle in southern Oregon.

Cox, Caroline. 1998. Lessons from leafy spurge and yellow starthistle. *Journal of Pesticide Reform* 18(1):2-6.

A review of literature and experiences in controlling two noxious weeds: leafy spurge and yellow starthistle. One Washington State University experiment cited indicated that “artificial cattle grazing (clipping that simulates grazing) reduced the ability of four perennial grasses to resist invasion by yellow starthistle” (p. 4).

[Note: While it is becoming popular to state that starthistle invades healthy grassland or grassland that isn't being currently grazed by livestock, the above WSU study needs to be considered in relation to any proposals to restore starthistle infested areas, or to prevent the plant's further spread.]

On integrated management: "Near Myrtle Creek, Oregon, densities of yellow starthistle were 'greatly reduced' following introduction of the [*Eustanopus*] weevil, combined with a reduction of cattle grazing and increases in competition from perennial grasses" (p. 5).

Hedberg, Kathy. Undated. Bugs put bite on star thistle. *Lewiston Morning-Tribune*(?)

This article describes the multi-insect biological control approach of the Clearwater National Forest toward yellow star thistle, and its public education outreach.

[As biological control, not pesticides, will ultimately be the most likely landscape-scale control of starthistle, this effort is worth tracking and joining in.]

Harris, P. 1997. Monitoring and impact of weed biological control agents. In Andow, D.A, D.W. Ragsdale, and R.F. Nyvall, eds. *Ecological Interactions and Biological Control*, pp. 215-233. Boulder CO: Westview Press.

This chapter describes successful biological control of diffuse knapweed in Canada.

Kennedy, A.C. 1997. Deleterious rhizobacteria and weed biocontrol. In Andow, D.A, D.W. Ragsdale, and R.F. Nyvall, eds. *Ecological Interactions and Biological Control*, pp. 164-177. Boulder CO: Westview Press.

This chapter describes the work of U.S. Department of Agriculture scientists to identify rhizobacteria that suppress the growth of downy brome (cheatgrass).

Seastadt, T.R., N. Gregory, and D. Buckner. In review. Control of diffuse knapweed using insects in a Colorado grassland. <http://culter.Colorado.EDU/~tims/knapweed.pdf>

This study documents successful biological control of diffuse knapweed near Boulder, Colorado.

WATERSHEDS

Riparian and aquatic wildlife habitat

Belt, George, Jay O'Laughlin, and Troy Merrill. 1992. *Design of Forest Riparian Buffer Strips for the Protection of Water Quality: Analysis of Scientific Literature.* Idaho Forest, Moscow, ID: Wildlife and Range Policy Analysis Group, University of Idaho.

This reviews hundreds of studies regarding the effectiveness of buffer strips in logging settings: trapping sediment or nutrients, moderating stream temperatures, providing large organic debris, controlling cumulative effects, and providing food and cover. Few generalizations can be made, given the differences in geography, vegetation, buffer strip widths, etc. in the studies. What is clear is that any claims for the effectiveness of a given buffer strip can't be based on one or two selected studies.

Case, Richard, and Boone Kauffman. 1997. Wild ungulate influences on the recovery of willows, black cottonwood and thin-leaf alder following cessation of cattle grazing in northeastern Oregon. *Northwest Science* 71(2):115-126.

This study addresses the relative impact of cattle and cattle/elk/deer on riparian vegetation in Oregon's Wallowa-Whitman National Forest, on the Starkey Experimental Forest. The study traced willow, thin-leaf alder, and black cottonwood responses for two years after cattle were removed (1991). Deer and elk enclosures were compared with the areas that were only cattle-free after 1991.

"Two years following the removal of livestock, increases in biomasses ranged from 48% to 568% outside of exclosures and from 131% to 745% inside exclosures... In two years, black cottonwood within exclosures increased 50 cm (151%) in height. Outside of exclosures cottonwood increased 25 cm (72%)" (p. 119).

Biomass of willows combined increased 439% inside exclosures, 235% outside; crown volume of all willows 550% inside and 195% outside.

"Limitations to shrub recovery may partially be explained by a lack of reproductive vigor; only 10% of willows produced catkins following livestock removal... Most of the reproductive individuals in 1993 were inside of the exclosures; 34% of the willows inside exclosures produced catkins as compared to 2% outside exclosures" (p. 121).

Beaver removed large stems both within and outside the exclosures.

"A passive restoration approach which is simply the removal of those anthropogenic perturbations that are causing degradation or preventing recovery has been suggested to be the first necessary step in ecological restoration and

probably the most important... The significant growth response of all hardwood species [in this study] in the absence of cattle and/or wild ungulate herbivory is indicative of the success of this approach" (p. 123).

"Following more than a century of heavy grazing, growth increases were dramatic. However, wild herbivores had significant and negative influences on the rate of recovery on the height of black cottonwood, and height, crown area, crown volume, biomass and reproductive output of willows" (p. 124).

Machtans, Craig, Marc-Andre Villard, and Susan Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. *Conservation Biology* 10(5):1366-1379.

An Alberta study examining the frequency of bird movements through 100-meter wide riparian buffer strips before and after harvesting of adjacent forest. The buffers form connections between forest fragments and the surrounding continuous forest.

The results are quite site-specific (e.g., only one before-and-after treatment site and only two buffer strips), but "...demonstrate that corridors are used more frequently than clearcuts by forest bird species for movement and that, at the very least, they can maintain the movement rates observed in undisturbed sites. Secondly, movements of some species truly represented natal dispersal through corridors" (p. 1376).

Long-term monitoring will be needed to see if the fragments connected by corridors will retain more forest species or keep them in greater abundance than fragments without corridor connections (p. 1376).

Caveat: "The myriad of species that may or may not use corridors and the specific circumstances governing when they will use them make answering the 'corridor question' difficult. Undisputable evidence of corridor value is probably species-dependent and will require many more experiments" (p. 1376).

Riparian/Aquatic Habitat: Effects of Livestock Grazing

Belsky, Joy, Andrea Matzke, and Shauna Uselman. 1999. A survey of livestock influences on stream and riparian ecosystems in the western United States. Draft unpublished paper. Portland, OR: Oregon Natural Desert Association.

Review of the findings, differences among, and methods of approximately 150 published scientific studies regarding direct and indirect effects of livestock activities on stream and riparian habitats.

"As noted earlier, an extensive literature search did not produce peer-reviewed, empirical papers reporting a positive impact of cattle on riparian areas when those areas were compared to ungrazed ones" (p. 7).

"Several recent papers [four citations] describe the benefits of reduced cattle stocking rates and newer grazing systems, such as rest-rotation and deferred grazing, and discuss how riparian zones regain herbaceous and woody cover and improved water quality while being grazed. Their studies contrasted newer grazing systems with more traditional and destructive systems, such as year-long grazing and high stocking rates, rather than with historically protected or recently ungrazed treatments" (p. 8).

Variability among studies can be affected by: (1) inherent variability found between and within watersheds (e.g., channel morphology, soils, climate, hydrology, riparian species); (2) inadequacy in study design (e.g., lack of adequate replication); (3) differences in study design (e.g., different meanings attributed to "heavy" and "light" grazing); (4) grazing inside exclosures by invertebrates (e.g., abundant exclosure vegetation can be attractive); (5) prior grazing history (e.g., as affecting erosion, elimination of native vegetation); and (6) variable time lags (e.g., recovery of woody vegetation along stream sides may begin immediately after grazing is terminated while the recovery of channel form may take hundreds of years; p. 10.)

"The current debate over the suitability of livestock grazing in arid western ecosystems has resulted in supporters declaring that 'livestock sometime benefit streams'. All studies, both formal and informal, contradict this statement. Livestock don't benefit stream and riparian communities, water quality, or hydrologic function in any way [see Table 1]" (p. 16).

Regarding a 1996 Draft EIS requirement that movement of unsatisfactory livestock sites toward satisfactory status must occur at 70% of the rate of livestock-free areas: "...Even if improvement occurs [e.g., with reduced grazing intensity, fencing, or increased rest from grazing], the vegetation may be dominated by non-native species and recovery will take at least two-to-four times as long to occur with grazing as without [citations]" (p. 16).

Table 1 in this document summarizes the findings of about 150 studies on the influence of livestock grazing and trampling on:

- Water quality (nutrient concentrations, bacteria/protozoa, sediment load and turbidity, water temperature, and dissolved oxygen);
- Stream channel morphology (channel depth, channel width, channel stability during floods, water depth, channel bed gravel, channel bed fine sediments, streambanks, streambank angle, streambank undercuts, channel form, pools);
- Hydrology (overland runoff, peak flow, flood water velocity, summer and late-season flows, and water table);
- Riparian zone soils (bare ground, erosion, litter layer, compaction, infiltration, and fertility, algae, and higher submerged and emergent plants);
- Streambank vegetation (herbaceous cover, biomass, productivity, and diversity; overhanging vegetation; tree and shrub biomass and cover;

species composition; vertical and horizontal structure; plant age-structure; plant phenology; and plant succession);

- Aquatic and riparian wildlife (fish diversity, abundance and productivity and behavior; invertebrate diversity, abundance, and species composition; amphibians and reptiles diversity, abundance and species composition; bird diversity, abundance, and species composition; mammal diversity, abundance, and species composition; and threatened and endangered species abundance).

Kauffman, Boone, and WC Kreuger. 1984. Livestock impacts on riparian ecosystems and streamside management implications. A review. *Journal of Range Management* 37(5):430-437.

Numerous studies of the impacts of livestock grazing on riparian systems.

"...[S]tream habitats should be identified as separate management units from the surrounding upland ecosystems" (p. 434).

"Land management agencies responsible for managing livestock grazing have not adequately considered the influence of grazing on the other uses and users of riparian ecosystems" (p. 435).

Ohmart, Robert. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. Chapter 16 in: Krausman, Paul, ed. *Rangeland Wildlife*. Denver, CO: The Society for Range Management.

Extensive review in a Society for Rangeland Management book.

On the importance of leaving some areas free of livestock: "A small mammal, reptile, or amphibian species could decline to extirpation and the passage not be noticed" (p. 250).

"Reduction in livestock numbers is not a management approach to eliminate degradation to riparian habitats" (p. 256).

"Unquestionably, grazing can be used to enhance habitat for some avian species...Most of the species added are habitat generalists whose numbers are common in the uplands. Those species thought to be declining and possibly being eliminated are foliage volume or thicket specialists" (p. 268).

Of relevance to proposed standard that grazing in allotments of less than satisfactory condition will be required to move toward satisfactory condition at 70% the rate of ungrazed sites: "With managed grazing riparian healing time is twice (16-20 years) and maybe 4 times (32-40+ years) longer than exclusion" (p. 272).

"In riparian habitats, vegetative components, in general, fulfill the ecological needs of the greatest array of wildlife species. In their order of importance are

tree species and their densities, foliage profile, foliage volumes in the profiles, horizontal patchiness, and shrub species and their densities" (p. 273).

Etc.

Taylor, Daniel. 1986. Effects of cattle grazing on passerine birds nesting in riparian habitat. *Journal of Range Management* 39(3):254-258.

This study speaks to the possibility of long-term recovery of formerly-grazed systems.

Transects through nine sites with different recent cattle grazing histories and other human disturbances along the Blitzen River in the Malheur National Wildlife Refuge in southeast Oregon were regularly walked during the summers of 1981 and 1982.

Area 1: Extensive cattle use through 1974/75, then some winter grazing since. Dredging activities in 1978 and 1979.

Area 2: Extensive cattle use through 1977/78, then winter grazed in 1981/82.

Area 3: No cattle use after 1974/75 except 1979/80.

Area 4: No cattle use after 1974/75 except winter grazing in 1976/77.

Area 5: Fenced and undisturbed since 1940.

Area 6: No cattle use after 1970, but part of an active campground.

Area 7: No cattle use after 1970.

Areas 8 and 9: No cattle use after 1980.

[Note: The above detail is included, because it is the type of different histories present in the vacant allotments --age three to 20 years, and differing in ecosystem characteristics and human influence, and it provides important information.]

"Area 5, undisturbed for 4 decades, had 10 times as much shrub volume as the four most heavily grazed areas" and more than double the volume of Area 4 (p. 255).

"Area 5 had 5 to 7 times as many birds as Areas 8 and 9, which were heavily grazed until 1980. Area 4 had the second highest number of birds, and was grazed only once since 1975 (winter 1976/77), but Area 5 still had 94% more birds in 1981 and 53% more in 1982" (p. 255).

"The time since a transect was last grazed was significantly and positively correlated with the number of passerines for the 7 transects without additional

documented disturbances...and for all 9 transects regardless of additional disturbances" (p. 255).

"Area 6 [i.e., the area with no cattle grazing for 10 years, but current use as a campground] had a low relative abundance of birds compared to amount of vegetation" (p. 256).

"The shrub strata and most of its associated bird species can be adversely affected by cattle grazing, while the upper canopy and its birds are not [citation]. However, cattle grazing in riparian zones over several decades can eliminate or reduce the upper canopy by preventing the establishment of saplings [citation]" (p. 257).

"It is has been estimated that 70-90% of all natural riparian habitat with in the U.S. has already undergone extensive alteration [citation]. Livestock grazing is possibly the major cause of habitat disturbance in most western riparian communities [citation]" (p. 257).

WILDLIFE

Wildlife: Habitat and Grazing

Bock, Carl E. and Jane H. Bock. 1988. Grassland birds in southeastern Arizona: Impacts of fire, Grazing, and alien vegetation. In: *Conservation of Grassland Birds* ICBP Technical Publication No. 7. Cambridge, England: International Council for Bird Preservation.

The Bocks have documented long-term changes in the vegetation and fauna both inside and outside of a 3160 ha sanctuary in southeastern Arizona's desert grassland, which has been free of livestock since 1968. Their book, *The View from Bald Hill*, summarizes many of their findings. This article describes changes in the bird community supported by the grasslands after cattle were removed. Among their findings:

- "The exotic grasslands were ornithologically impoverished. Heterogeneous mixtures of native plants, providing as they do a greater variety and abundance of seeds and insects, clearly comprise far superior habitat for most of the avifauna."
- "Stands of the exotic lovegrasses do not appear to be spreading on the sanctuary, and it may be that undisturbed mixtures of native species can resist further encroachment. . . Elsewhere, cattle are encouraging the spread of these alien species, because these animals prefer to feed on native grasses."
- "In certain severely degraded southwestern rangelands, the African exotics can at least reduce erosion and provide some minimal wildlife cover."

However, our data suggest that seeding exotic species is a less desirable management alternative than giving native vegetation the time and opportunity to recover something of its prehistoric vigor and diversity.”

DeLong, Don, and Jim Yoakum. 1994. Review of "Rx Grazing to Benefit Watershed-Wildlife-Livestock [Anderson *et al.* 1990a]. Unpublished(?) paper.

This is a careful, readable, fascinating dissection of the claims of three researchers (Anderson, Franzen and Melland) that vegetation in the Hart Mountain National Antelope Refuge of southeastern Oregon benefited during 1979-1987 from cattle grazing in terms of increased litter cover and higher number of perennial plant species through the Refuge. The authors then concluded that watersheds had been enhanced during this period, due to the cattle grazing.

DeLong and Yoakum write, "We found these conclusions to be unfounded for 6 [actually more] major reasons":

1. "...[T]here is reasonable doubt that more than a few, if any, sampled plots were grazed by cattle" (p. 3).

DeLong and Yoakum overlaid the locations of permanent plots on maps of cattle distribution and utilization during these years. "Results suggests [sic] that plots located in upland areas could have remained ungrazed by cattle between 70% and 100% of the time during the period 1979-1987... plots located in riparian areas could have remained ungrazed by cattle between 20% and 100% of the time... However, which plots were grazed during which years cannot be determined from available information" (pp. 4-5).

2. The study lacked predefined control plots, so there is no ability to separate livestock grazing effects from other influencing factors (p. 6).
3. It is questionable whether changes that occurred on plots are representative of the Refuge.

For instance, as their primary example, Anderson, et al. generalized to 15,000 acres based on one 100-foot diameter plot in which they estimated vegetation cover two times, once in 1979 and once in 1987. The authors did not attempt to sample the various types of sites in the Refuge: "... [N]early 25% of the plots were used to characterize less than 3% of the HMNAR [i.e., Refuge], and approximately 3% of the plots were used to characterize about 30% of HMNAR" (p. 7)

4. Anderson, *et al.* stated that the most significant benefit during 1979-1987 was the number of new perennial species. But DeLong and Yoakum found the following in the data of Anderson, et al: "A higher number of perennial forb species in 1987 compared to 1979; concurrent declines in grass and forb cover during the same period; a more or less static cover of shrubs, litter and moss/lichen cover; and no detectable change in the

number of perennial grass species...[which] does not support the argument that watershed conditions improved" (p. 9)

5. Shrub cover in the Refuge is in excess of levels considered healthy, and that didn't change during the years cited.
6. The claim that five of the eight years were below-normal for precipitation is not substantiated.
7. Anderson, *et al.*'s speculations that cattle "preconditioned" forage for pronghorn are not backed up by any evidence, and pronghorn mostly browse, while cattle graze.

[Note: The entire idea of "preconditioning" forage is questioned on p. 19.]

8. Anderson, *et al.* did not provide data about the number of years that sampling took place, the number of plots that were sampled during each sampling periods, and the plots weren't statistically representative of the Refuge.

"Based upon presented findings, there is no reason to believe that cattle were responsible for any changes in vegetation or wildlife (i.e., pronghorn). There also is insufficient evidence to suggest that vegetation conditions improved" (p. 25).

The claims by Anderson, et al. that livestock had benefitted pronghorn and vegetation on the Hart Mountain National Antelope Refuge were repeated by Oregon State University's (OSU's) Rangeland Department, praised by Krueger and Buckhouse at OSU, and appeared in subsequent Anderson documents (see **pp. 26-27**). Hence the crucial importance of analyzing the raw data on which such claims are made.

This analysis of Anderson, et al. by DeLong and Yoakum is a model of scientific precision, thoroughness, clarity, and reasonableness.

[Note: This is a classic example of the need to view the raw data upon which claims are made, as well as data that such claims ignore.]

Fleischner, Thomas. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8(3): 629-644.

Fleischner reviews scientific literature re: the adverse ecological impacts of livestock grazing in arid western lands in terms of (1) alteration of species composition of communities; (2) disruption of ecosystem functioning; and (3) alteration of ecosystem structure.

Medin, Dean, and Warren Clary. 1990. Bird and small mammal populations in a grazed and ungrazed riparian habitat in Idaho. Research Paper INT-425 (July). Ogden, UT: U.S. Department of Agriculture, Intermountain Research Station

Comparison of breeding birds and small mammals between a seasonally-grazed livestock riparian area and an adjacent 14-year exclosure in east-central Idaho. It is an example of how livestock and livestock-free areas provide habitat for certain different species. Present in larger numbers or only in the exclosure: Vesper and savannah sparrows, breeding red-winged blackbirds, vagrant shrews, water shrews, northern pocket gophers, and Great Basin pocket mice, mink, and muskrats. Some other species were present in larger numbers or only in the livestock areas: Killdeer, willet, long-billed curlew, and territorial Brewer's blackbirds.

Wildlife: Grassland, Sagebrush, and Pinyon-Juniper Habitat

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Paper presented at The Symposium on Management of Forest and Range Habitats for Nongame Birds. Tucson, AZ, May 6-9, 1975.

Discusses the importance of foliage height diversity, percent cover, foliage volume, plant species diversity, and foliage height to bird species diversity. Birds restricted to climax communities may have relatively low dispersal powers, narrow ranges of tolerance and low reproductive rates. Discusses importance of climax communities in maintaining a group of bird species with narrow ecological tolerances.

Discusses importance of pinyon pine in maintaining populations of pinyon jay and Clark's nutcracker, and densities of wintering Townsend's solitaires, reliant on juniper berries.

Urges land managers to be cautious of using data gathered over only one season or a short period of time. Notes importance of rare species. Urges managing for maximum number of species at density levels that most closely reflect natural conditions. Species with narrow tolerance ranges need management attention.

Bock, Carl, Victoria Saab, Terrell Rich, and David Dobkin. 1993. Effects of livestock grazing on neotropical migratory landbirds in western North America. *In: Finch, DM, and PW Stangel, eds. Status and Management of Neotropical Migratory Birds*; 1992 September 21-25; Estes Park, CO. General Technical Report RM-229. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 296-309.

A review of available literature on responses of birds to livestock grazing in Intermountain shrubsteppe (among 3 other habitats). Data for Intermountain shrubsteppe are limited, but "only 3 of 23 species probably have been positively affected [by livestock grazing] while 13 probably have been negatively influenced, and at least 7 species showed mixed responses."

"Virtually nothing is known about effects of grazing on birds of coniferous forests."

One of the birds probably negatively affected by grazing based on their requirement for cover for ground nests is the ferruginous hawk, as follows:

Medin, Dean, and Warren Clary. 1990. Bird and small mammal populations in a grazed and ungrazed riparian habitat in Idaho. U.S. Department of Agriculture, Intermountain Research Station Research Paper INT-425 (July).

One of the birds probably negatively affected by grazing based on its requirement for cover for ground nests is the ferruginous hawk, of concern in Oregon and Idaho as follows:

- Category 2 (Endangered Species Act)
- Critical in Oregon (OR DF&W)
- Sensitive (FS Regions 4,6)
- Rare or uncommon in Idaho (CDC Heritage Data Base)
- Limited in Oregon, needs active monitoring (CDC Heritage Data Base)
- Priority species in Idaho (ID F&G)

Some others probably negatively affected include:

- Swainson's hawk [Vulnerable in Oregon (OR DF&W); Cause for longterm concern in Idaho (CDC Heritage Data Base); and Limited in Oregon, needs active monitoring (CDC Heritage Data Base)]
- Grasshopper sparrow [Limited in Oregon, needs active monitoring (CDC Heritage Data Base)]

Indicated as probably being negatively affected by livestock grazing in forests is the Lewis woodpecker:

- Sensitive bird species (US Fish and Wildlife Service)
- Critical in Oregon (OR DF&W)

- Limited in Oregon, in need of active monitoring (CDC Heritage Data Base)]

The conclusion is one of the scientific arguments for retaining all vacant allotments as vacant: "There is an urgent need for long-term, well-replicated, field studies comparing bird populations in grazed and ungrazed shrubsteppe and montane coniferous forest habitats."

Idaho Partners in Flight. 1998. Draft: Sagebrush shrub portion of a Bird Conservation Plan. http://www.blm.gov/wildlife/plan/pl_id_10.pdf

This rough draft of a bird conservation plan for sagebrush scrub habitat focuses particularly on sage grouse, because "It is a sagebrush obligate, it has a large home range, and requires expanses of intact sagebrush habitat." Likely to be petitioned for listing in the near future.

Paige, C. and S. A. Ritter. 1999. *Birds in a Sagebrush Sea: Managing Sagebrush Habitats for Bird Communities*. Partners in Flight, Western Working Group. Boise, ID.

"Nationally, grassland and shrubland birds show the most consistent population declines over the last 30 years of any group of bird species", with 63% of shrubland bird species declining. Livestock grazing and trampling damages native vegetation, affects species composition, harms microbial crusts, and increases invasive species. The presence of livestock can increase brood parasitism by brown-headed cowbirds.

"The greatest change to sagebrush plant communities came with the invasion of non-native annual grasses and forbs, particularly cheatgrass ... cheatgrass spread like an epidemic across the Intermountain West along transportation corridors and in the wake of grazing ..."

"Cheatgrass is a rapid colonizer of disturbed sites and a persistent resident, replacing native species".

"Cheatgrass invasion fundamentally alters fire and vegetation patterns in sagebrush habitats," creating a bed of fine fuel that causes fires to flash across the landscape, and areas to burn as often as every 3 to 5 years. "Cheatgrass dominance eventually creates a uniform annual grassland perpetuated by large, frequent fires and void of remaining patches of native species. Restoring native plants is then extremely difficult if not impossible".

Recommends no net loss of sagebrush habitat in a landscape, discusses management options.

"Historically, small, patchy fires occurred at frequencies of 25 to 100 years".

Discusses impacts of habitat fragmentation, invasion of non-natives, mining and oil and gas development, farming and residential development.

Includes a great lit. cited section!

Saab, V. and T. Rich. 1997. *Large-scale Conservation Assessment for Neotropical Migratory Land Birds in the Interior Columbia River Basin*. USDA Forest Service General Technical Report PNW-GTR-399. . Portland, OR: Pacific Northwest Research Station

Discusses declines in shrub-steppe and other bird communities in the Interior Columbia Basin, and possible habitat-related causes.

MONITORING

Bock, Carl, Jane Bock, and Hobart Smith. 1993. Proposal for a system of federal livestock exclosures on public rangelands in the western United States. *Conservation Biology* 7(3):731-733.

Grassland researchers Jane and Carl Bock describe the need for large, representative public land tracts of livestock-free grassland (e.g., the currently livestock free half of the HCNRA). Two main reasons:

"First, if components of the native flora and fauna are intolerant of the activities of grazing mammals (and the [scientific] evidence suggests some are), these species have comparatively few places left to live [in the West]. Second, the lack of large representative tracts of ungrazed grassland in many areas makes it nearly impossible to determine the actual consequences of livestock grazing. It has been an experiment largely with a control."

Hobbs, Richard J. 1989. The nature and effects of disturbance relative to invasions. In Drake, J.A., H.A. Mooney, *et al.* eds. *Biological Invasions: A Global Perspective*. Chichester, NY: Wiley.

This study (described above in the Disturbance and Exotics section) is one of many possible examples of why the BLM needs, with any of its vegetation treatments, to provide matched, untreated control plots. Hobbs describes a study he carried out in each of five western Australian shrub and woodland communities. To the two halves of one meter square plots, he added 100 *Avena fatua* (an annual grass) and 100 *Ursina anthemoides* (an annual forb). To random plots he then added 50 grams complete fertilizer and/or disturbed the soil to a depth of 5cm, by breaking the soil crust and turning the soil.

"While we must still rely heavily on historical and observational data on invasions, we must also make use of other tools including modeling and experimentation to help explain some of the questions arising from observational studies. Experimentation has been used relatively little to date and, clearly, some natural systems are more suitable for experimentation than others. There is

nevertheless a wealth of information to be obtained from relatively simple and inexpensive experimental techniques.” (conclusion, **p. 402**)